Siboga-Expeditie
IVa

THE FORAMINIFERA OF THE SIBOGA EXPEDITION

BY

J. HOFKER

PART II

Families ASTRORHIZIDAE, RHIZAMMINIDAE, REOPHACIDAE, ANOMALINIDAE, PENEROPLIDAE

WITH AN INTRODUCTION ON THE LIFE-CYCLE OF THE FORAMINIFERA

With 26 plates and 22 textfigures

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INTRODUCTION.

THE LIFE-CYCLE OF THE FORAMINIFERA.

I. Life-cycle of *Miliolina circularis* (Bornemann). (See Pl. XXXIX, figs. 6—13).

Material. Many specimens have been gathered in mud, which occurred between heaps of *Mytilus edulis*, attached to the gulf-breakers at the shore of Scheveningen (Holland). This material was kept in little vessels, and after some weeks an abundance of individuals was observed, creeping along the walls of the vessels or on seaweed. But even more were surrounded with a layer of mud and attached to weeds, etc. The existence of those cysts of mud in the genus *Miliolina* has already been stated by SCHNEIDER [1]) (see also RHUMBLER [2]), but not in all cases of reproduction: SCHAUDINN [3]) describes the forming of young in *Miliolina* in which the whole sarcode becomes free from the test before division into rounded parts takes place. It is however possible, that he described here the reproduction of the microspheric form, and I also found very few encystated microspheric specimens, so this encystation probably is only characteristic for the megalospheric individuals. It is also probable, that SCHAUDINN's material did not need a cyst, due to the circumstances of his cultures. Those cysts looked like little yellow or brown corpuscules and would have escaped my examination, if stained material had not been mounted in canadabalsam and thus the secret of those little mud-balls had been discovered.

Methods. The material, containing somewhat 300 individuals, was divided into two parts, one was stained with borax-carmine, the other brought into paraffin (after fixation with 5% acidum trichloraceticum in sea-water, mixed with some drops of acidum aceticum, in which the chalk is dissolved). It was sectioned then and the preparations were stained with haematoxylin (after Ehrlich). They were stained very deeply, so that the sections became always opaque. A solution of alcohol 50% was made, in which was dropped some acidum hydrochloricum, in which the sections, attached to the glass-slits, were differentiated, till the chromatin of the nuclei was clearly visible; than they were washed in a vessel, containing a solution of some drops of concentrated NaOH in 50% alcohol. Here the red colour of the haematoxylin changes in dark blue, and the sections are removed in alcohol 95%, in which they must be washed thoroughly. After this they were transmitted in a vessel, containing ether, which was shaken before with quicked lime, so that no water remained in it. After having been washed in ether, they must

1) SCHNEIDER, A., Beiträge zur Kenntniss der Protozoen (Zeitschr. wiss. Zoologie, vol. 30, suppl., 1878).
2) RHUMBLER, L., *Saccammina sphaerica* Sars (Zeitschr. wiss. Zoologie, vol. 57, 1894, p. 187, Pl. 22, fig. 25).
3) SCHAUDINN, F., Die Fortpflanzung der Foraminiferen (Biol. Centralbl., vol. 14, 1894).

be quickly removed into xylolum and then in canadabalsam; the preparation must be covered with a cover-slit [1]).

Microspheric generation.

Some large specimens, never covered with mud, proved to be microspheric. In sections

Textfigure 12. Sections through microspheric individual of *Miliolina circularis* (Bornemann);
a: tangential section, showing many nuclei, some of them in a stage of division (× 520); *b*: nearly median section, showing some nuclei and in the central part two socalled "restbodies" (× 520); *c*: view on the surface of a nucleus, showing the regular arrangement of the endosomes, (× 900); *d*: optical section from the same nucleus (× 900).

they showed many (± 100) nuclei, oval shaped, with a very typical structure. [GERVAIS' observation [2]), that in a large specimen of *Miliolina* somewhat 100 young were formed, fully agrees with this number of nuclei. We must however observe, that SCHULTZE [3]) counted only 40 young].

1) It is not possible to stain Foraminifera with haematoxylin, when total preparations are requested, as the haematoxylin stains the organic material of the shell very deeply and differentiation afterwards is not possible, the shell being not permeable enough for the different solutions. Therefore all my total preparations have been made with borax-carmine after GRENACHER, differentiation was procured by means of nitric acid joined immediately to the solution of borax-carmine. The process of staining lasted twelve hours.

2) GERVAIS, Sur un point de la physiologie des foraminifères (Comptes Rendus Acad. Scienc., vol. 25, 1847).

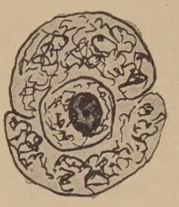
3) SCHULTZE, M. S., Beobachtungen über die Fortpflanzung der Polythalamien (Quart. Journ. Micr. Sci., vol. 5, 1856).

The internal parts of these nuclei are hyaline and cannot be deeply stained with haematoxylin, nor with borax-carmine. But, pressed against the membrane, about twenty six "endosomes" can be traced, so that the nucleus shows the typical "vesicular" type. The internal side of these endosomes is rounded, the external, which is pressed against the membrane, is flattened. Length of the nuclei about 10 μ, breadth 6 μ. (textfig. 12).

Textfigure 14.
Section through a somewhat older individual of *Miliolina* with relatively small proloculum, showing nucleus, (× 520).

Megalospheric generation.

Young specimens have been met with in abundance, also fullgrown individuals in large quantities. Most of the fullgrown ones had a relatively small proloculum, some a larger one. Most of the young specimens showed a very large proloculum. One of the microspheric specimens contained two megalospheric young ones in its shell. They showed a relatively small proloculum.

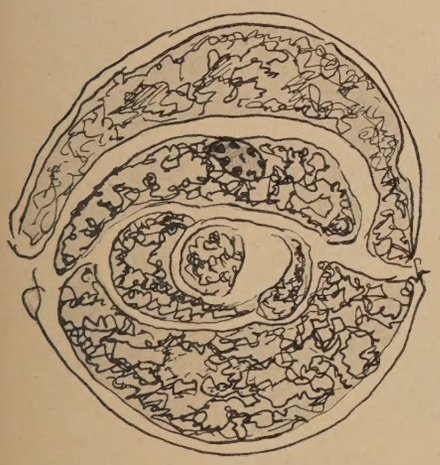


Textfigure 13.
Section through a young individual of *Miliolina* with small proloculum, showing its nucleus, (× 520).

Youngs with relatively small proloculum. They show in the proloculum a vesicular nucleus, very like those, found in the microspheric specimens; dimensions of the nucleus 12 × 9 μ; diameter of the proloculum ± 30 μ (textfig. 13).

Older specimens with relatively small proloculum. They show in the central chamber a large nucleus, rounded, with very distinct endosomes. Diameter of the nucleus ± 18 μ (textfig. 14).

Fullgrown specimens with relatively small proloculum. Some specimens show



Textfigure 15. Section of specimen of *Miliolina* with small proloculum, showing one of the 12 nuclei present (× 520).

Textfigure 16. Two sections through specimens of *Miliolina* with small proloculum, with dividing nuclei, one showing a restbody in the central part (× 520).

yet a single nucleus, but most of them are encystated in an oval accumulation of mud. These specimens generally show more than one, often eight or ten nuclei, maximum 17 (textfigs. 15 and 16).

Some specimens very well showed how the wall of the mud-cyst is formed. When we call the side of the mouth the fore-side and the opposite one the back-side, we find that the cyst is always built round the fore-side, so that the back-side of the shell forms a part of the wall of the cyst, and the largest cavity of the cyst is situated at the fore-side (textfig. 17).

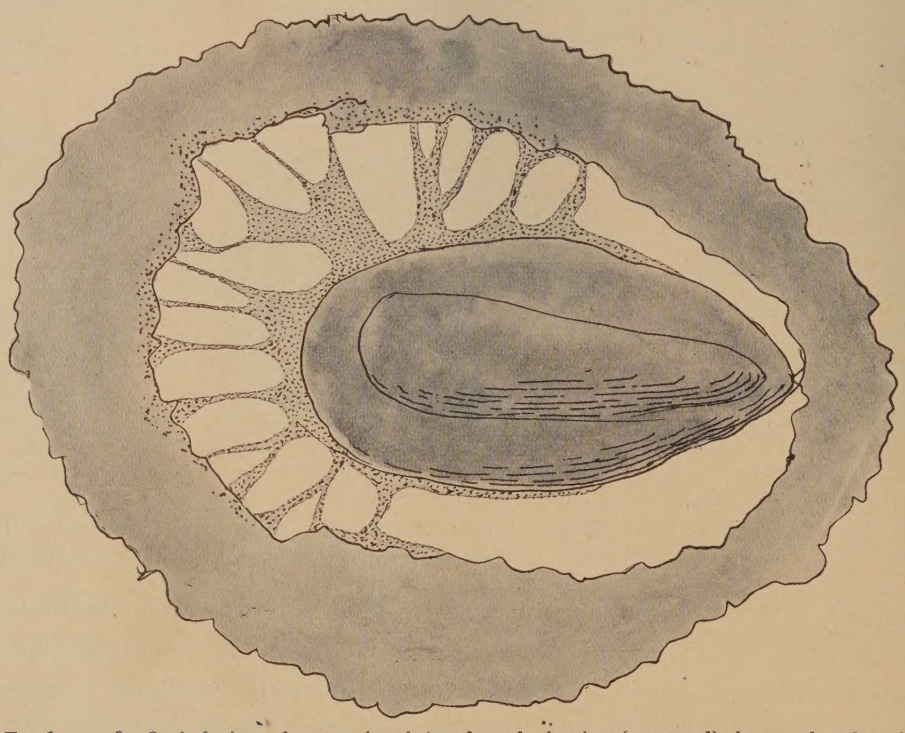
During the forming of the cyst, the protoplasm of many pseudopodes, protruding from the shell, is cementing the particles of which the wall of the cyst is to be composed (text-fig. 18). As these particles are often quite like those, found in the external chambers as food-bodies, I believe, that most parts of the walls of the cysts are formed, especially with respect to their internal layer, by means of food-remains. The fore-side of the cyst shows the thicker wall.

Textfigure 17. Cyst of mud, showing the protruding *Miliolina* at one side (× 520).

When the cyst has been finished, the protoplasm withdraws into the shell.

Now the nucleus, which was simple hitherto, is divided, to begin with into two nuclei, which are also found in the first chamber (diameter of the nuclei ± 22 μ).

Other individuals show four, eight, ten or twelve nuclei. While the number of the nuclei increases, their diameter diminishes. Often two nuclei were observed, laying close together, both with a sharply lengthened point, as

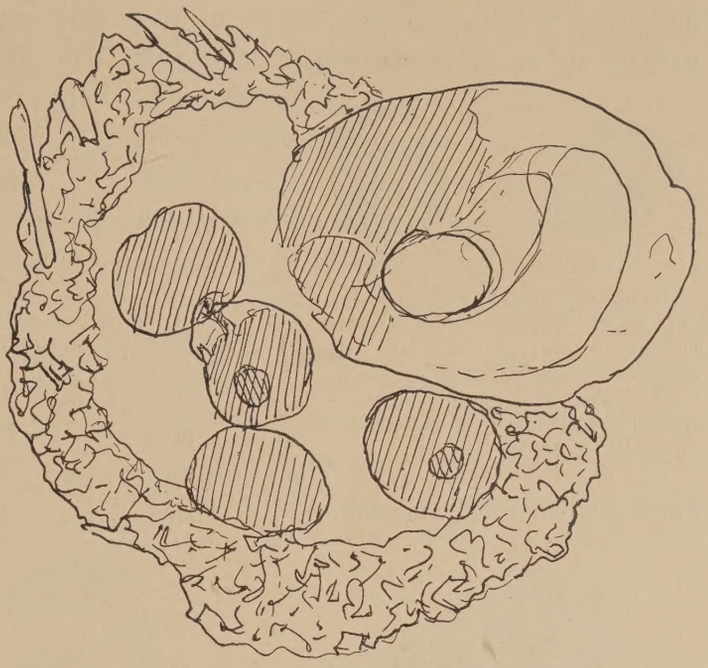


Textfigure 18. Optical view of a cyst, just being formed, showing (punctated) the pseudopodes of protoplasm, cementing the mud-particles together (× 520).

if they had been just finishing division. I believe that all nuclei are formed by simple division.

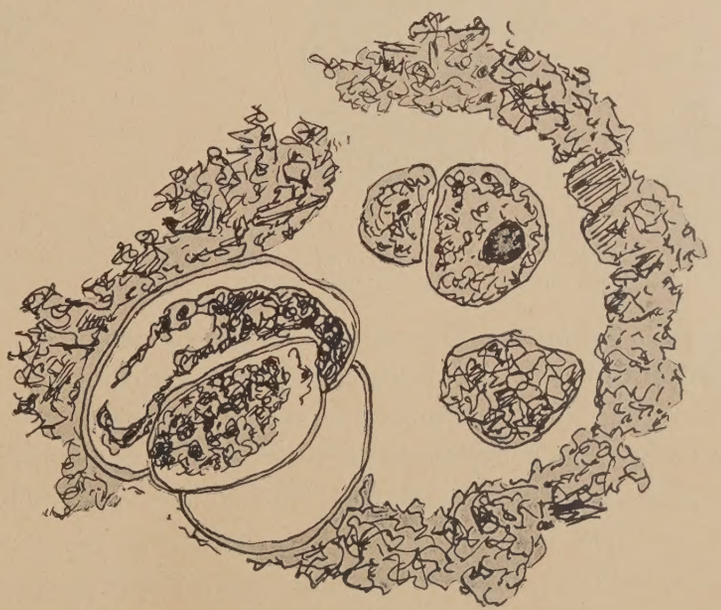
It is very peculiar, that no trace of a chromidium could be stated in anyone of the encystated megalospheric specimens.

A tolerable quantity of cysts has been found, in which the cavity was filled up with two to ten rounded bodies, while at the same time the shell of the *Miliolina* was empty (textfigs. 19 and 20). These bodies show a fine membrane and a mouth with a short neck, imitating the shape of the proloculum of *Miliolina* (textfig. 21); the neck chamber is connected with the first one by a narrow foramen. The bodies are of a large size (± 40 μ) and show consequently the same diameter as the proloculum of the young specimens with large proloculum. Every one of them possesses a nucleus, which cannot be distinguished from those, found in the shells of *Miliolina*. Some of these young proved to have two nuclei, which is a very remarkable fact, but it occurred only very rarely.



Textfigure 19. Optical view of a cyst, in which eight plasmodiospores were found. The protoplasm is sketched by means of lines; four spores are to be seen, two of which show a nucleus; the larger part of the parent shell is empty (× 520).

When all round bodies in the cyst have been formed, there remains in the proloculum of the *Miliolina*-shell only a rest of protoplasm together with a round, obviously liquid, chromatical mass, a rest-body. The forming of the round bodies must take little time, for we find only a small number of cysts, in which only few of these bodies are found, while at the same time in the shell a larger quantity of protoplasm with some nuclei is visible.



Textfigure 20. Section through cyst of *Miliolina* with some plasmodiospores (× 520).

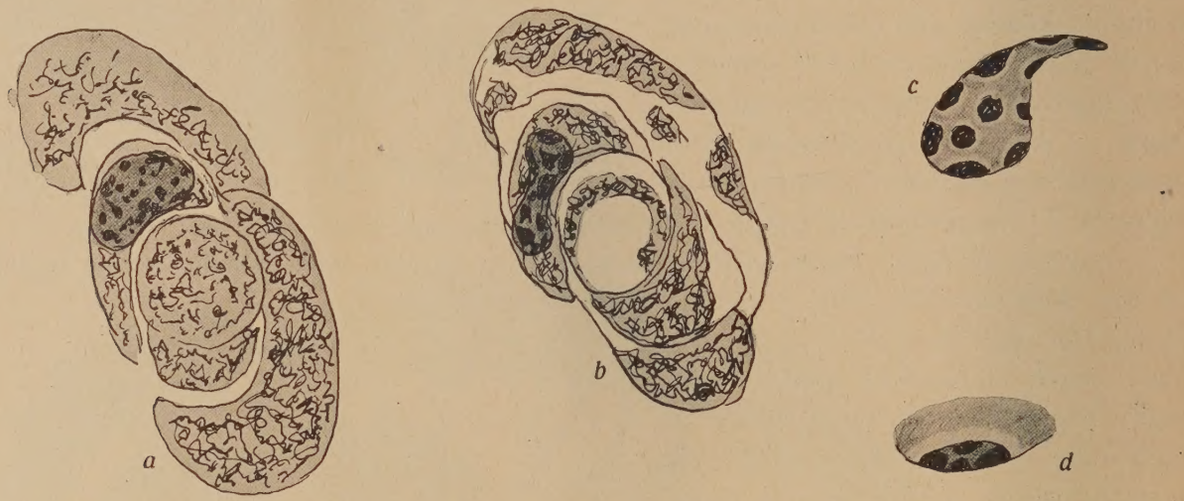
Young specimens with large proloculum. They show a nucleus — not distinguishable from that, found in the "round bodies" — which is of a nearly globular shape. The diameter of the first chamber is that of the round bodies, viz. 40 μ. Near the nucleus in individuals, which show already four or more chambers, an irregular stainable body is situated: the chromidium already mentioned by LISTER and other authors. Then the nucleus is very large and shows distinct endosomes (textfig. 22).

Older specimens with large proloculum. They possess a single very large nucleus, which is situated in one of the chambers surrounding the proloculum. At first this nucleus shows relatively small microsomes, but afterwards these seem to fuse to large endosomes, which are not homogenous, but contain four or five more highly stainable masses each. The most fullgrown specimens possess a very well stainable nucleus of a quite homogenous internal structure.

Textfigure 21. Sections through plasmodiospores of *Miliolina*, *a*: showing the neck-chamber totally, *b*: just through the neck-chamber, showing that it is a low, flattened chamber, beginning with a narrow proloculum. The latter specimen shows two nuclei (× 520).

Discussion.

In older works it is supposed that megalospheric forms give rise to microspores only. The microspores of *Miliolina* have been observed by WINTER [1]), who describes them as uniflagellate. I showed here, that it is also possible that the megalospheric animals form megalospores, giving rise directly to megalospheric forms with large proloculum. The latter derives from megalospheric forms with smaller ones.



Textfigure 22. *a*, *b*: Sections through young specimens of *Miliolina* with large proloculum, showing nucleus (× 520); *c*: nucleus of a specimen of A_1-generation, showing very remarkable endosomes (× 840); *d*: a single endosome, very highly enlarged, showing an inner structure.

So in our material, consisting of about 300 living individuals, are found three forms, which can easily be distinguished from each other:

1) Microspheric forms.
2) Megalospheric forms with a small proloculum.
3) Megalospheric forms with a large proloculum.

The forming of microspores could not be studied in this material.

LISTER, in his beautiful account on English species of *Nummulites*, has already mentioned the fact, that megalospheric specimens may give rise to megalospheric young (*Cornuspira*, *Peneroplis*, *Orbitolites*, *Cristellaria*), but the fact was not studied in living material and some of LISTER's examples must be considered as erroneous, the so-called brood of young being in

1) WINTER, F. W., *Peneroplis pertusus* (Archiv für Protistenkunde, vol. X, 1907, p. 18).

these cases nothing else than tests, accidently having found their way in dead larger shells of the same species [1]). The forementioned fact, however, has been stated in material, preserved in alcohol, by LISTER in the species *Orbitolites complanata* [2]). So we can be sure, that this phenomenon occurs also in other genera of the Foraminifera; it must be a general one.

SCHAUDINN [3]) however, when studying *Calcituba*, describes the forming of megalospores ("Plasmodien") by megalospheric individuals. This must have been the same phenomenon, as I have met with here, but the forming of the nuclei has been described erroneously by SCHAUDINN, or the nuclei in *Calcituba* show other peculiarities as in other Foraminifera. (Yet I have observed in *Rotalia beccarii* some phenomena, which may be the same as the forming of nuclei by means of a chromidium, mentioned by SCHAUDINN.)

RHUMBLER [4]) has given fine examples and an exhaustive description of all cases, hitherto described, dealing with propagation of megalospheric specimens by means of those plasmodia, which he calls "Plasmodiosphaerae". According to RHUMBLER we have to call the first megalospheric generation (deriving from a microspheric parent), megalospheric shells and those individuals, deriving from megalospheric parents by means of plasmodiosphaerae, we must call plasmodiospheric. [According to SCHAUDINN [5]), these "Plasmodiosphaerae" are already mentioned by LANG in his "Lehrbuch" and he calls them "Plasmodiosporen".]

In *Calcituba* is shown an example of more than one single plasmodiospheric generation. As I have already mentioned, when dealing with *Miliolina* from the North Sea, *Calcituba* belongs to the MILIOLIDAE.

A very peculiar way of reproduction is called by RHUMBLER (l. c. 1910—11, p. 317) cytogamy (= plasmogamy). It was a good idea of this author to place this kind of propagation close to his "Plasmodiosphärenbildung". A conjugation of nuclei was never observed, though the phenomenon was thoroughly studied by SCHAUDINN (1895): After the plasmogamy the forming of the megalospores begins. It seems to me, that this plasmogamy has no other reason than the alteration of the state of the cytoplasm, to make it ready for rapidly succeeding divisions. RHUMBLER describes from Laysan [6]) a pair of cytogamic parents with four young, the first chambers of which are much larger than the megalospheres of the parents. This seems a very striking phenomenon, but it will be nothing at all peculiar, if regarded in the sense of what we have seen in *Miliolina*. There are only two parents instead of a single one.

It will be clear that plasmogamy has nothing to do with sexual reproduction, as SCHAUDINN has suggested. RHUMBLER (l. c. 1910—1911, p. 318) observes in this connection: "Ein Umschlag der Generationen, von makrosphärischen zu mikrosphärischen oder umgekehrt findet also nach der Cytogamie ebensowenig statt, als auch die Verkoppelung selbst die Vereinigung ungleichnamiger Individuen keinenfalls zur Voraussetzung hat". We must direct our attention also to

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1) LISTER, J., On the dimorphism of the English species of Nummulites (Proc. Roy. Soc. London, vol. B, 76, 1905, pp. 312, 316).

2) LISTER, J., Contributions to the life history of the Foraminifera (Phil. Transactions Roy. Soc., London, vol. 186, 1895, p. 435, figs. 50 and 51).

3) SCHAUDINN, F., *Calcituba polymorpha* Roboz (Zeitschr. f. wiss. Zoologie, vol. 59, 1895).

4) RHUMBLER, L., Die Foraminiferen der Plankton-Expedition (Part I, 1910—1911).

5) SCHAUDINN, F., Untersuchungen über die Fortpflanzung einiger Rhizopoden (Arb. Kais. Gesundsheitsambte, Bd. 19, 1903, p. 550).

6) RHUMBLER, L., Die Foraminiferen von Laysan und den Chattam Islands (Zool. Jahrb., Abt. Systematik, vol. 24, 1906, p. 32, Pl. 2, fig. 7).

the views on this point, which are exposed by HERON-ALLEN [1]). This author comes also to the conclusion, that SCHAUDINN was wrong when considering the two parents as sexual. But whether his opinions about the real significance of this "association" of pairs are right (the author suggests that we deal here with a kind of budding) can only be made out by further investigations. I believe that, if the author had consulted RHUMBLER's beautiful work (1910—1911), which has not been mentioned in his literature-list, he would probably have come to other conclusions.

II. Life-cycle of *Eponides* (= *Pulvinulina*) *repandus* (Fichtel et Moll).

(See Pl. XXXIX, figs. 1—5; Pl. XL, figs. 1, 3 and 4).

Material. In the brackish water of the Zuiderzee this species is a very common one. Hundreds of specimens can be found during the summer season in a single cubic centimeter of mud. In the northern part of the Zuiderzee, in which the water is much more saltish, the specimens show normal features; in the southern part however the shell is very thin, without much chalk-incrustations at the ventral side and its diameter is but to 300 μ.

I have described this form as *Pulvinulina repanda* var. *concamerata* Montagu in my article in the "Flora en Fauna der Zuiderzee", 1922, p. 148, fig. 44.

Methods. The material was gathered in the years 1920 and 1921 and in 1927 and 1928. The mud was fixated with alcohol 95% or with acidum trichloraceticum and the Foraminifera were treated as has been described already, when dealing with *Miliolina*.

When examining quantities of mud, gathered with a "happer", every student knows the excrements of small Gastropoda and Arthropoda, globular bodies of fine mud. In my material, gathered in September 1927 and 1928 occurred numerous yellowish bodies, apparently excrements too. But when destructing them with a needle, each of them proved to contain a specimen of *Eponides*, with living protoplasm. This phenomenon of forming cysts by means of mud has also been observed in a few cases by BRADY [2]) in *Truncatulina lobatula* and by HERON-ALLEN [3]) in *Discorbina*. BRADY says in this connection: "*Truncatulina lobatula* is the commonest and perhaps the best known of all rotaline Foraminifera; it nevertheless presents one interesting peculiarity that seems to have escaped notice heretofore, namely, the tendency displayed by adharent specimens to form for themselves a covering of loosely agglutinated sand. The drawings (Pl. CXV, figs. 4 and 5) represent two examples of this habit of growth: in fig. 4 the sandy nidus remains in its natural condition, intact; in fig. 5 a portion of the covering has been removed to show the calcareous shell within. When the contour of the sandy envelope is regular and convex, as in the former case, the specimens may easily be mistaken at first sight for *Webbina haemisphaerica*, though always distinguishable by the different mode of aggregation of sand-grains, which in the present species are retained in their position chiefly, if not entirely, by the sarcode of the living animal, whilst in *Webbina* they are embedded in organic cement and form a compact wall".

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1) HERON-ALLEN, E., Contributions to the study of the bionomics and reproductive processes of the Foraminifera (Phil. Trans. Roy. Soc. London, ser. B, vol. 206, 1915, pp. 235—237, pp. 245—252).

2) BRADY, H. B., Rep. Voy. Challenger, Zoology, vol. IX, Foraminifera (1884, p. 660, Pl. CXV, figs. 4 and 5).

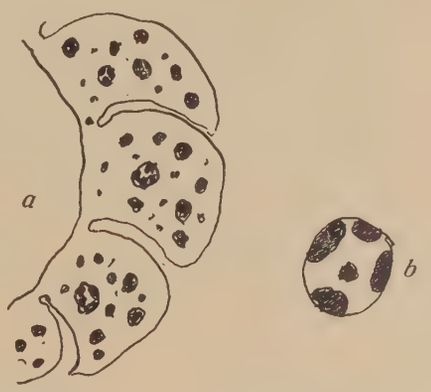
3) HERON-ALLEN, E., Bionomics (Phil. Trans. Roy. Soc. London, ser. B, vol. 206, 1915, p. 238).

I gathered and fixated hundreds of these encystated individuals. Some have been mounted, after having been stained, in canadabalsam and others have been cut in sections with a thickness of 7 μ. I stained them in the same way as I have described above.

I treated some material with FEULGEN's and ROOSENBECK's method [1]); the results were very peculiar. Specimens with small proloculum, fixated in June and July, showed a deep colouring of the nucleus. Specimens with large proloculum fixated in September, which showed with haematoxylin a well-developed chromidium, together with a dark stainable nucleus, showed very clearly the chromidium, but the nucleus was not to be stained. Obviously the substance of the chromidium is to be regarded as real chromatic, but the nucleus lacked chromatin; consequently the nucleus degenerates when the spores are formed.

Microspheric generation.

Living microspheric forms occur in the very large quantity of samples only during spring and summer, never abundant and always in fullgrown specimens. In November and in winter I found only young specimens, possessing only three whorls of chambers. The first chamber measures about 8 μ, the chambers of the last whorls are somewhat irregularly shaped. They show a multitude ($\pm$ 25) of nuclei, very like those, which I have described in *Miliolina*. The nuclei contain five or more large endosomes. In one specimen I could not observe any nucleus at all, but a large quantity of chromatic bodies was scattered through the protoplasm (textfig. 23). Yet the individual was certainly microspheric. This agrees with the facts, mentioned by SCHAUDINN [2]), dealing with *Polystomella crispa*: "In diesen jungen Tieren ist die Kernsubstanz nicht in einem differenzierten Kern vorhanden, sondern sie erfüllt in unregelmässigen Körnchen und Strängen diffus das ganze Plasma", and "Nach meiner früheren Schilderung vermehren sich die Kerne während des Wachstums der mikrosphärischen Individuen auf directe Weise weiter. Die grössten peripheren Kerne beginnen dann bald durch Zerfall Chromidien zu bilden .... sodass am Ende des vegetativen Daseins kein einziger differenzierter Kern mehr existiert".



Textfigure 23. *a*: Part of a microspheric specimen of *Eponides*, stained with borax-carmin, showing irregular masses of chromatin (× 242). Some of these masses are shaped like true nuclei, as is the case in most specimens observed. *b*: single nucleus, more highly magnified (× 870).

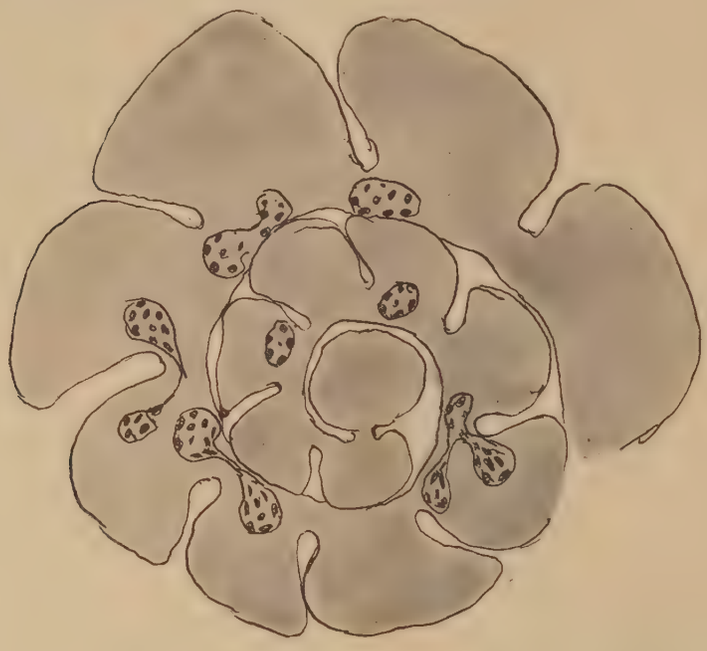
Megalospheric generation.

Living specimens are not found in winter, only in summer and autumn (September f. i.). In winter only dead megalospheric shells can be met with, in September lots of individuals, showing an encystation with mud, have been found, all being megalospheric.

In summer (June) I found megalospheric fullgrown specimens with small proloculum (diameter 25 μ), together with young ones, showing a very large first chamber (diameter $\pm$ 32 μ). Those with small proloculum often show more than one nucleus (these nuclei are formed by a

1) FEULGEN, R., Die Nuclealfarben (ABDERHALDEN's Handbuch der biologischen Arbeitsmethoden, Abt. V, vol. 2, p. 1055, 1926).
2) SCHAUDINN, F., l. c. 1903, pp. 550—552.

simple process of fission of the first, single nucleus, as is seen in textfig. 24bis); those with large proloculum always a single one (textfig. 24). In the case, in which we could distinguish two different megalospheric generations, different with respect to their initial chamber, it would be clear, that those generations, when occurring in the same sample in somewhat equal quantities, would be very easy to distinguish from each other. Yet I pointed out in the first Part of this Monograph, that all stages between those extreme forms could be found, as the plasmodiospores of the two generations B and A_1 are not always exactly of the same size, even if they derive from the same parent. I was so fortunate to find in my material of *Eponides* from the Zuiderzee two really different groups of megalospheric specimens with respect to their first chambers. I measured 99 initial megalospheric chambers, enlarged × 870. The diameters were from 16 to 36 mm., as is seen in textfig. 25. But this figure also shows, that two



Textfigure 24bis. Decalcified specimen of megalospheric form (A_1) of *Eponides*, showing the fission of the nuclei, only the central part sketched (× 520).

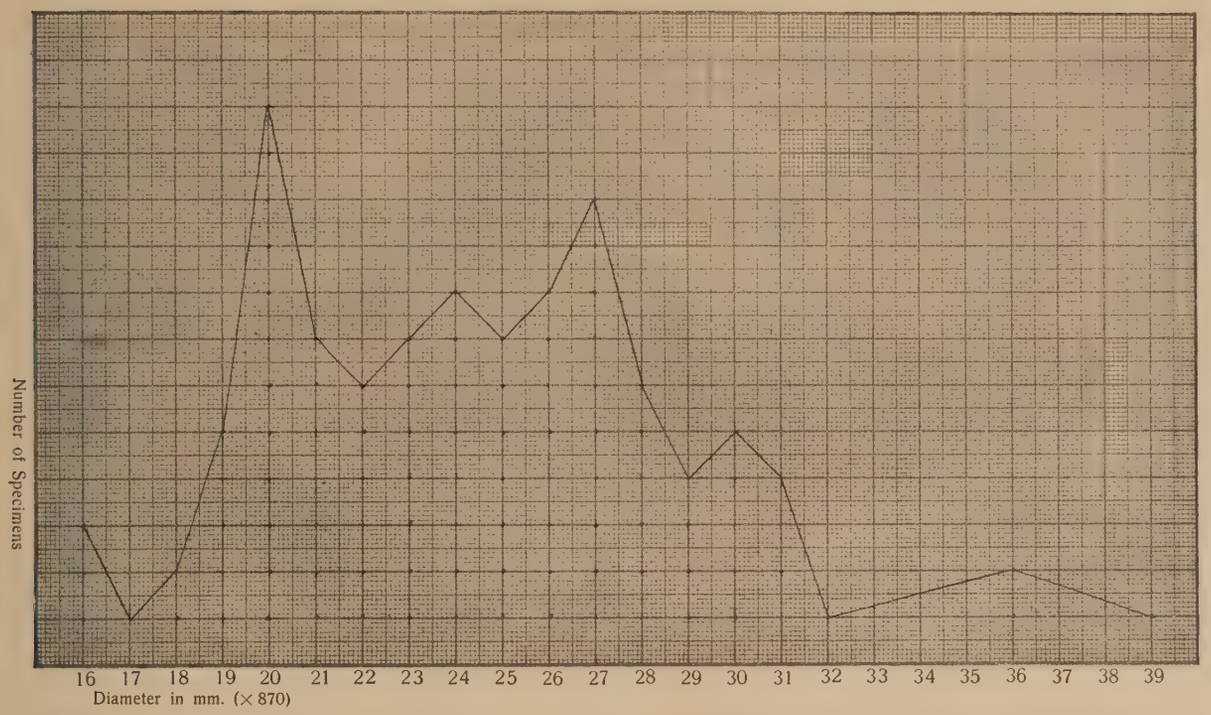
Textfigure 24. *a*: Forma A, with large proloculum, of *Eponides*, decalcified and stained by the method of FEULGEN, showing its single nucleus, chromidium, and, in the central chamber, a "rest-body". *b*: Forma A_1, stained by the same method, showing its large quantity of nuclei, when adult, and, in the centre a kind of "rest-body" (× 260).

groups of diameters must be distinguished, one with small diameter, the other with a larger one.

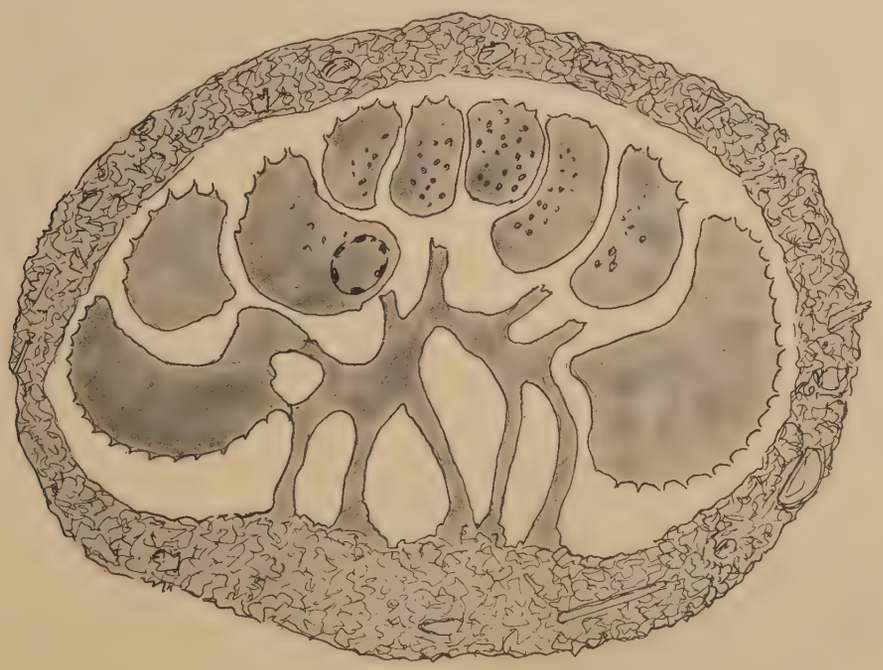
In autumn all encystated individuals are of the type with large proloculum.

The cysts. They are composed of fine material, very fine sand-grains etc., very like

the food-bodies, which are found in the protoplasm. The walls of the cysts are thin at the dorsal



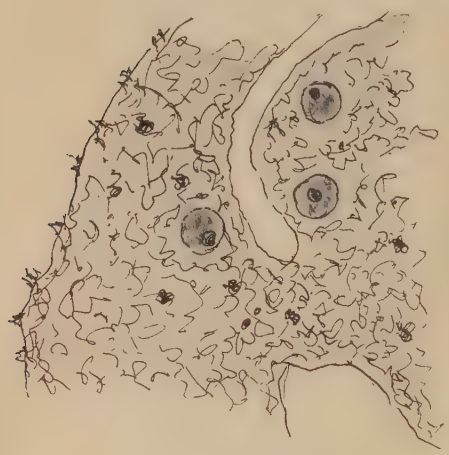
Textfigure 25. Diagram of the diameters of prolocula of 99 specimens of megalospheric *Eponides repandus*. Horizontally are indicated the measures of prolocula in mm., when enlarged 870 ×; vertically are set down the number of specimens, observed. When joining the tops of those quantities, a curve with two tops can be constructed.



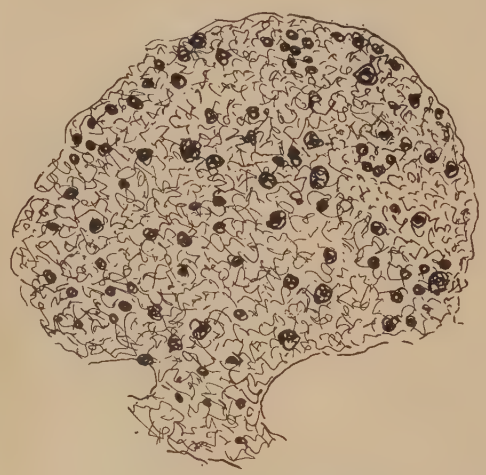
Textfigure 26. Transverse section through encystated *Eponides repandus*, showing the mud wall of the cyst, the nucleus and the chromatic particles scattered through the central part of protoplasm, the umbilical canal system reaching the ventral cystwall (× 340).

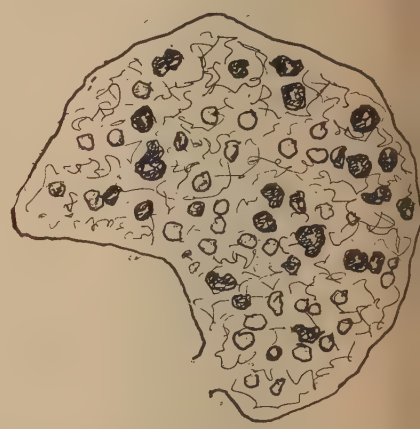
side of the shell, but thickened at the ventral one, so that the external side of a cyst shows

no indication, where the ventral side of the enclosed Foraminiferum is situated, the ventral and dorsal side of the cyst being equally vaulted. Between the shell and the wall of the cyst remains a little space, somewhat broader at the ventral side (textfig. 26). The shell is attached to



Textfigure 27. Section through protoplasm of *Eponides*, from outer chambers, showing three zooxanthellae (× 870).





Textfigure 28. Sections through central plasma of *Eponides*, first stage of encystation, showing the chromidial bodies (× 870).

the wall of the cyst by means of a protoplasmic string, protruding from the shell through the openings of the umbilical canalsystem. As this string is especially found in younger cysts (the state of the protoplasm shows that they are young) I am inclined to believe, that this canal-protoplasm has something to do with the forming of the cyst-wall.

Different stages of the protoplasm of *Eponides* found in the cysts:

1. The internal diameter of the first chamber is about 30 μ. In the fifth chamber is found a typical, round, nucleus of the vesicular type. But the chromatin-bodies are not so regularly shaped as those of *Miliolina*. They are only found at the periphery of the nucleus. Diameter of the nucleus about 25 μ. Sometimes a nucleus is also met with in the following chamber. The protoplasm of the chambers of the first whorls is homogenous and shows no traces of more stainable bodies; that of the later chambers is often filled up with food-particles, whilst also zooxanthellae are often found, especially arranged in a layer at the outer margin of the shell. Diameter of these zooxanthellae about 7 μ (textfig. 27).
2. The protoplasm in the neighbourhood of the nucleus shows very small bodies (diameter $\pm$ 3 μ), stainable with haematoxylin, borax-carmine and with sulphurous acid fuchsin (textfig. 28), and refracting the light more highly than the surrounding protoplasm. This high exponent of refraction of the chromatin-bodies has already been observed by WINTER [1]). With high magnification can be observed, that these bodies are not homogenous, but show darker stained spots. Often, especially in later stages, they show very primitive stages of division, very like those of *Vahlkampfia limax* (Calkins [2])) (textfig. 29).

Textfigure 29. Division of a nucleus, formed by the chromidium, in encystated individual of *Eponides repandus* (× 2100).

1) WINTER, F. W., *Peneroplis pertusus*, 1907, p. 18.
2) CALKINS, G. N., The biology of the Protozoa (Philadelphia and New York, 1926, fig. 26).

3. The protoplasmic body shows round vacuoles and the protoplasm itself is broken into small globular bodies of darker stainable plasm, in which the "nuclei", described in 2, are visible (textfig. 30*a*).
4. All the protoplasm is differentiated into microspores; the older ones show fine flagellae. The zooxanthellae have disappeared and here and there remains of nuclear and of other dark, stainable substances are met with. The large nucleus has vanished.

Textfigure 30. Two sections through chambers of two different individuals of encystated *Eponides repandus*, showing the protoplasm filled up with nuclei; just beginning sporulation. *a*: individual with small, *b*: with larger nuclei, suggesting a sexual differentiation (× 870).

5. The larger part of the cyst has vanished. The shells are nearly empty, in natural state of a brownish colour; rests of the protoplasm remain in the shell.

Discussion.

As the reproduction of microspores takes place within a cyst, many authors will have overlooked it. This explains the fact, that only very few publications deal with reproduction of Foraminifera. In *Rotalia*, at least in our regions, the forming of microspores has only been observed in autumn; microspheric specimens are found during winter and it will be very probable (as SCHAUDINN showed it for *Polystomella crispa*), that these forms derive from zygotes, formed by fusion of the microspores. SCHAUDINN (l. c. 1903) has described the fusion of the microspores, the forming of the zygote; he observed the growth of the microsphere until shells with five chambers had been formed [see also LISTER [1])].

1) LISTER, J. J., Roy. Inst. of Great Britain, weekly evening meeting, Febr. 15, 1907.

In spring and summer megalospheric specimens are formed, at first those with relatively small proloculum, later on also those with larger first chamber. It is very probable, that those with small proloculum descend from a microspheric individual by the forming of megalospores and that those with a larger first chamber derive from a megalospheric specimen, as I could show. [In 1860 M. S. SCHULTZE [2]) described the production of megalospheric young in *Rotalia nitida* (probably the same species, with which we are dealing now). Parent and young were megalospheric]. In autumn only specimens with large proloculum were found, only forming cysts and microspores. It is also probable, that the primitive division-stages, found after the forming of small nuclei out of a chromidium, represent a kind of reduction of chromatin. It has, however, never been stated, that a double division of the chromatin exists here. But there is no reason why in all organisms reduction of chromatin coincidates with a double division of the nucleus. If a reduction of chromatin takes place, we may expect a fusion of two microspores to form the 2x-generation, beginning with the microspheric form. It is also very probable, that microspores from different parents fuse, for the number of young microspheric specimens is very small, and it would be large if spores of the same parent did fuse, for this would indeed have been easy enough. There seems to be a difference between the sizes of the microspores of different parents, as in some shells the microspores were somewhat larger than in others (compare textfig. 30*a* with 30*b*).

Textfigure 30bis. Plasmodiospore of *Eponides repandus*, just having come free from the parent, creeping elong the surface of a coverglass, and possessing two initial chambers (× 244).

So we have found that the typical alteration of generations, mentioned here, is connected with the alteration of the season. LISTER (l. c., 1895, p. 435) mentions, that he stated young in megalospheric *Orbitolites* only in a gathering, made in November. SCHNEIDER (l. c. 1878) described the production of microspores of *Miliolina* in September and October, and the forming of megalospores in spring. Here the same seasonal development was shown. The microspheric generation, the asexual one, is the most resistant, and lives during the winter, in which often a large part of the water of the Zuiderzee is frozen.

We have here a typical case of metagenesis: an asexual — microspheric — generation, followed by intermediate stages — megalospheric — with small proloculum, from which descend the third sexual generation — megalospheric — which forms the gametes, microspores. These microspores fuse and so produce a zygote, which grows out to the microspheric form. (See SCHAUDINN l. c., 1903).

Some authors, f. i. WINTER, mention in their accounts on this matter only a single megalospheric generation. Especially WINTER's figure (l. c., 1907, p. 16, fig. A) has been copied in several modern handbooks. Yet the simple mode of reproduction by means of flagellospores

1) SCHULTZE, M. S., Die Gattung *Cornuspira*, etc. (Archiv für Naturgeschichte, vol. 26, 1860).

of the megalospheric generation, supposed by WINTER, is doubtful, even in *Peneroplis pertusus*. For he describes, that only younger specimens of megalospheric *Peneroplis* formed flagellospores, while others grew to individuals with a large number of chambers. He says, when dealing with these specimens (1907, p. 19): "Über die Lebensgeschichte der makrosphärischen vielkammerigen Peneroplengreise kann ich vorläufig nichts aussagen, ich vermute, dass sie gametenlos bleiben. (Tatsache ist, dass sie ein nur sehr unvollkommenes extranukleares Kernnetz haben, aber einen oder mehrere grosze Makronuklei besitzen. Im letzten Fall liegen einige in Kammern weiter nach vorn. Vielfach fand ich auch solche, deren Centralkammern plasmafrei oder plasmaarm sind)".

There is very little doubt that these old individuals without chromidium and possessing more than one single nucleus, are quite the same generation as that, mentioned above as the form with small megalospheric chamber.

It is very sorry, that WINTER has not figured these old megalospheric individuals so that we cannot find data about the volume of the first chamber (see RHUMBLER, l.c., 1910—11, p. 316). But in my account on *Peneroplis pertusus* (see p. 141 of this work) I could measure the first chambers of the different forms [1]).

III. *Trimorphism.*

In 1925 I supposed, in my first study on Heterogamy in Foraminifera [2]), that the polymorphism of megalospheric forms was due to sexual differentiation, saying: "I suppose, that the repeated asexual production of megalospheric brood gives rise to a still greater difference with regard to the inner constitution of the specimens". This suggestion was a somewhat unnatural one, and I am glad that the large material, I studied now, gave me the opportunity to drop it; for I could state now, as we have seen, that in living specimens of two very different species of Foraminifera two forms of the megalospheric type exist, the one giving rise to megalospores, the other, which derives from megalospores, giving rise to microspores.

If intermediate forms, with respect to the diameter of the initial chamber, occur, this

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1) When working at the Zoological Station at Helder, Holland, in August 1929, I had the opportunity to study the forming of plasmodiospores by the A_1-generation of *Eponides repandus* from the North Sea. The individuals have a long period of rest (three weeks or more), in which no pseudopodia are formed. The protoplasm, at first of an yellowish brown colour with zooxanthellae, becomes greyish, when the zooxanthellae are totally resorbed. Large quantities of fat-drops are formed. The nucleus is divided amitotically into three or more nuclei, and in the last formed chamber a plasmodiospore is formed by protoplasm, surrounding a single nucleus. The external wall of this chamber is in the meantime dissolved and the plasmodiospore forms a second, much smaller, chamber. This chamber is filled up with quite hyaline protoplasm, from which are protruding a large quantity of pseudopodia by means of which the new individual leaves the shell of the parent (see Textfig. 30bis). So I have to point out that in *Eponides* the embryonic apparatus consists of two chambers, as I suggested it to be the case in the allied group of the NUMMULITIDAE.

I stated, that in the parent (A_1)-form, no trace of a chromidium in the protoplasm could be found. I observed also, that the plasmodiospores of the two-chambered stage show no nucleus (which must have been burst asunder, as I found several remains of endosomes) and the entire protoplasm of the first chamber (proloculum) of the plasmodiospore is filled up with an irregular chromidium.

So SCHAUDINN must be quite right, when he says, that the nucleus of the Foraminifera, at least in ROTALIIDAE (he himself studied *Polystomella*) can be formed by a chromidium, as we know, that later stages of the A_2-form show a nucleus as well as a chromidium. In the second chamber, however, no chromatin substance could be found; I believe that this second chamber is filled up with the motoreous part of the protoplasm. Such a second chamber, serving to hide the motoreous protoplasm, can also be found in the embryons of other Foraminifera (f. i. the neck-shaped chamber in PENEROPLIDAE and MILIOLIDAE), and the presence of such a chamber is obvious now. It is very peculiar, that the plasmodiospore is separated from the rest of the protoplasm of the parent as a globular mass of the protoplasm and that afterwards the second chamber is formed more by means of a kind of stringing than of budding, the way by which later chambers invariably are formed.

I have measured the first chamber of the parent-individual and the mass of protoplasm, forming the embryon, and I found that this mass was much larger than that of the proloculum of the parent. So we can state here once more, that in the family of the ROTALIIDAE the proloculum of the A_1-generation is smaller than that of the A_2-form.

2) HOFKER, J., Heterogamy in Foraminifera (Tijdschr. Ned. Dierk. Vereen., ser. 2, vol. 19, 1925. pp. 68—70).

may be due to the fact, stated by SCHAUDINN, that the megalospores, formed by the microspheric generation, do not have alltogether the same diameter.

So, dimorphism in megalospheric generation is not due to sexuality, but to different derivation. In connection with what has just been observed, we must say, that, when studying this dimorphism of megalospheric forms, we must only consider extremes, as intermediate forms generally descend from the microspheric generation, but we cannot be certain on that point.

I may repeat, however, what I said in my before mentioned note on heterogamy:

"So, in the extreme case, we have three forms in one species of Foraminifera, viz.: the microspheric and two megalospheric forms". I can add now to this sentence: these forms have all three their biological importance in the life-cycle of the Foraminifera, and no student on this group can give an exhaustive account on a species, without describing these three forms.

In my account on the PENEROPLIDAE I have stated with certainty, that the first megalospheric generation in this group is that with the large proloculum, and that the megalospheric forms with small proloculum form microspores. This fact shows, that the diameter of the proloculum itself is no indicator for the generation, but real trimorphism was also clearly shown in that group. As we have seen already, the diameter of the megalosphere only depends of the quantity of protoplasm of the parent-shell and of the facility with which the protoplasm divides into spores. The last fact is due to outer circumstances f. i. surface-tension.

Is trimorphism always to expect to occur in Foraminifera? Certainly there may exist also apogamy as it is found in other groups of Protozoa. As the microspheric generation can only be produced by microspores (with respect to the small volume of the proloculum), and microspores cannot be formed in the case of apogamy, only megalospheric forms would remain. So we can be sure, that in the case of apogamy microspheric forms would be totally absent.

It is also possible, that the forming of megalospheric forms with large proloculum does not take place. In that case only dimorphism would be stated. But it will be obvious, that, as we observed that heterogamy is found in connection with alteration of seasons, the intermittent succession and alteration of micro- and megalospheric generations will be too quick to coincidate with the alteration of seasons. So only in tropical seas dimorphism may be expected, if possible.

But even tropical genera, as *Gypsina*, *Calcarina* and *Baculogypsina*, show typical trimorphism, as I have shown in Part I of this Siboga-Report.

CUSHMAN stated trimorphism in a simple form as *Apterrinella Grahamensis* [1]), and so we can say, that this metagenesis, to which this trimorphism is due, can be expected in all genera of the Foraminifera, tropical as well as others.

Can it be found also in fossil material? A priori we must affirm it. I have shown it in more than one species of Foraminifera of the senonian of Maestricht, VAN RIJSINGE [2]) found it in the genus *Dictyoconoides* (tertiary), CUSHMAN mentioned it for *Margulina hirsuta*, MUNIER CHALMAS and SCHLUMBERGER for *Idalina antiqua* (tertiary).

So we can expect also trimorphism in fossil forms. UMBGROVE [3]) gave a short account on some species of *Lepidocyclina*, which, occurring in the same layer, would be grouped together

1) CUSHMAN, J. A., Contrib. Cushman Laboratory for foram. Research (vol. 4, 1928, pp. 68—69, Pl. 9, figs. 1, 4).

2) RIJSINGE, C. VAN, On the genus Dictyoconoides (Annals and Magasine of Natural History, 1929, in the press).

3) UMBGROVE, J. H. F., Neogene Foraminiferen van de Soengei Beboeloë, Pasir (Zuid-Oost-Borneo) (Summary in English) (Wetensch. Mededeelingen Dienst van den Mijnbouw in Ned. Indië, n^0 5, 1927, pp. 9—12, 13).

with respect to the form of the initial chambers. But as also other specimens of the same genus were found in those rocks, it is not easy, if even possible, to know in this case, what species or forms belong together in the same biological species with respect to trimorphism.

When dealing with fossil material, we have firstly to observe those species, which have no closely allied forms in the same horizon, and the characteristics of the three forms of these species must be carefully analysed. Only then it is possible to identify those forms, which occur together with the forms of allied species.

As CUSHMAN pointed out already, the three forms, called in this monograph A_1, A_2 and B, show different stages of development, as it is the case in *Idalina* and *Marginulina*.

It will be possible in this way to predict the characteristics of the three forms of a species, if only one, the microspheric form for instance, is known already. I have given an example in Part I of this monograph (p. 49), when dealing with *Baculogypsina tetraëdra*.

The relation of the three forms in a trimorphic species can be found, with respect to the initial chamber of the megalospheric form, in the following way (see LISTER, l. c., 1905, pp. 309—311):

The microspheric form gives rise to a distinct quantity of megalospores, equal to that of the formed nuclei. So the volume of each megalospore (and subsequently of each initial apparatus of the megalospheric young too) can be found, when we know the volume of the protoplasm of the microspheric parent. In the same way we can know the volume of the megalospores, formed by megalospheric specimens. I have tried this method with my material of *Miliolina* and the result was very satisfactory.

I found:

microspheric generation:

volume parent: 600 000 μ^3

number of nuclei: 110

volumes of spores: $\frac{600\,000}{110} = 5454\ \mu^3$

volume of the first chamber of megalospheric brood: round **5000** μ^3

megalospheric generation:

volume parents (encystated specimens): 110 000 μ^3

volume of spores: 7500 μ^3

number of spores: $\frac{110\,000}{7500} = 14$

number of spores, found in cysts: mostly 8 or 10

number of nuclei, found in parents: **14** to 16

volume micr.: volume spores meg. I: volume spores meg. II = 600 000 : 5000 : 7500 = **110 : 1 : 1,5**.

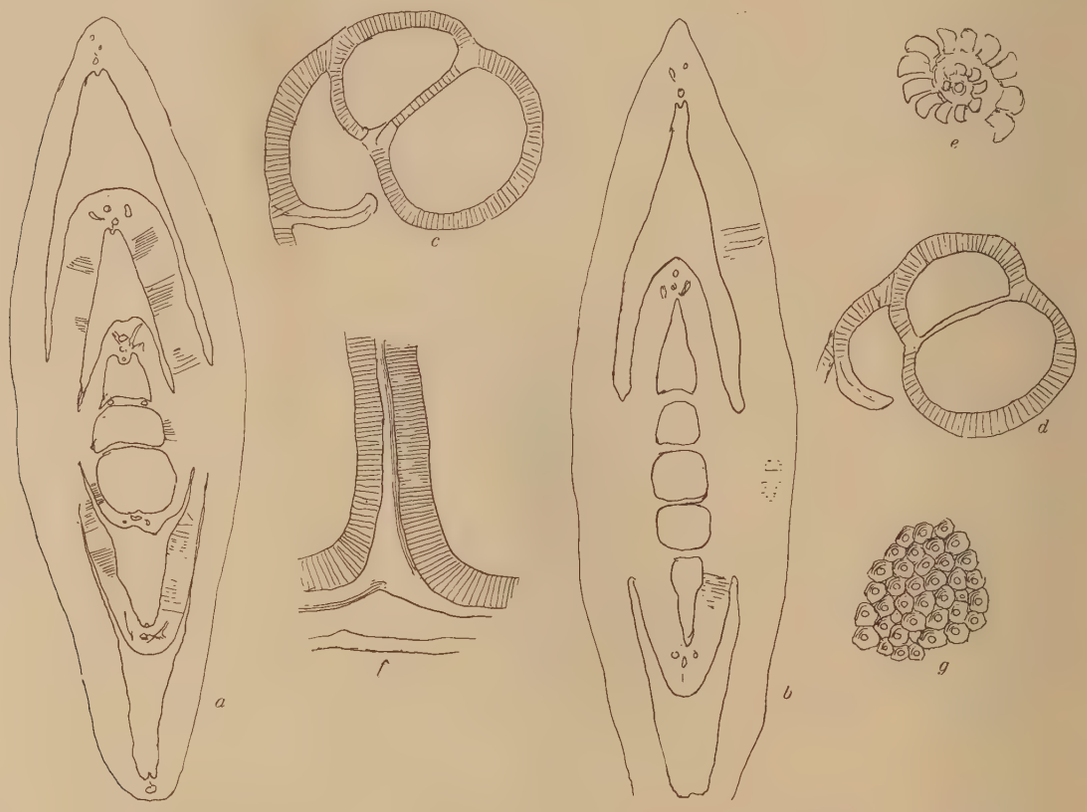
IV. *Trimorphism in Nummulites.* (See Pl. XLI, figs. 2—5; textfig. 31).

I will give here an account of a study, recently made on a fossil species of the genus *Nummulites*.

I obtained the stone, which consisted nearly completely of *Nummulites*-shells, all belonging

apparently to the same species, from the Leyden Museum ot Geology. As no locality and even no geological period, in which the marl could have been formed, was mentioned, I dared not try to find out its specific name. Therefore I will call it *Nummulites spec.* (See textfig. 31).

Firstly we must take into consideration, that a geological sample is something else than a gathering of recent forms by an expedition. For recent gatherings contain all stages of a species, if no seasonal differentiation intervenes. A geological sample, a piece of rock, consists merely of fullgrown species and contains the fullgrown shells of more than one year. Only the uppermost layer in the rock can possibly contain all stages, for, as in former geological periods



Textfigure 31. *Nummulites spec.*; *a*: transverse section through forma A_2, showing the large proloculum, the marginal canalsystem and the fine pores; *b*: transverse section through forma A_1; *c*. horizontal section through the embryonic apparatus of forma A_2; *d*: horizontal section through the initial chambers of forma A_1; *e*: horizontal section through the first coils of microspheric form; *f*: wall between two chambers; the wall is double and shows the canal running within; *g*: inner side of chamberwall, showing the funnel-shaped beginnings of the pores, characteristic for all typical NUMMULITIDAE.

the natural circumstances of the animals will not have changed much during the time, in which they formed the rock, most of them will have died after propagation and thus will be fullgrown. A sample in alcohol, however, also contains those forms, which are young and were still living before preservation.

Even when a rock has been formed by deposits on a shore, only fullgrown specimens form the larger part of it, as I have more than once observed, when examining recent shore-deposits.

My material of *Nummulites* consisted of hundreds of specimens, which could be easily divided into two groups, the one consisting of specimens of a diameter of about 7—10 mm, the other of specimens of smaller size. The last group consisted in its turn of two others,

specimens with a diameter of 2,5—5 mm and others with a diameter of 1 mm. So I had three groups, distinguishable by the diameter of the individuals.

I made longitudinal sections from these groups, and nearly 20 specimens from each were examined in this way. Especially the first chambers showed a striking difference.

The first mentioned form, of 7—10 mm, proved to be microspheric. The diameter of the first chamber, which is followed by a narrow spiral of chambers, as was already described by LISTER [1]), is about 14 μ.

The second form, large 2.5—5 mm, was megalospheric, and so was the third (large 1 mm). Yet there exists a remarkable difference between these two forms. Both possess an oval first chamber of about 280 $\mu \times 230\ \mu$. But the second chamber of the first mentioned form measured about 200 $\mu \times 130\ \mu$, of the third mentioned form 250 $\mu \times 160\ \mu$. These first two chambers are separated from the following whorls by a somewhat thickened wall and are so different from the other chambers, that they are always called embryonic chambers in literature and so it will be obvious, that these two chambers really formed together the young embryonic shell. The internal volume of these two chambers forms that of the embryonic protoplasm.

As we have seen, dealing with *Miliolina circularis*, the difference in size of the first chamber in this species is due to the difference in genesis of the embryons. So, if these embryons, when leaving the parental shell, consist of more than one single chamber, or these chambers are formed within a short time after leaving the parent, it is clear, that we must consider these two chambers as a single embryon and only the size of this entire embryon forms a standard of comparison. In living species the building of embryons with more than one single chamber has been stated by HERON-ALLEN [2]) (*Orbitolites complanata*) and by myself (*Eponides repandus*) and so there is nothing surprising in the fact, that also in other Foraminifera embryons of more chambers are formed.

It is very interesting, that other genera, such as *Orbitoides*, *Cycloclypeus*, *Lepidocyclina*, etc., also show an embryonic part of the shell, surrounded by a thicker wall.

Measuring the two chambers of the embryonic set of chambers of *Nummulites spec.*, we come to the conclusion, that the larger megalospheric form is that with the smaller embryon, and the smaller form that with a larger embryonic set.

If we could find a method to measure exactly the internal volume, especially of the microspheric shell, we could compare its volume with that of the initial apparatus of the megalospheric forms, as we did with *Miliolina*. There must be a relation, as LISTER (l. c. 1905, p. 213) has already shown. We do not know, however, if this relation is the same for all groups of the Foraminifera.

Here once more is clearly shown (I found it already in so many other species), that this species of Foraminifera forms three different forms:

1) Microspheric form, here the larger one.
2) Megalospheric form with smaller embryonic set of chambers, showing some characteristics of the microspheric one (f. i. its large diameter).
3) Megalospheric form with larger embryonic set of chambers, showing no characteristics of the microspheric one.

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1) LISTER, J. J., On the Dimorphism of the English Species of *Nummulites*, etc. (Proc. Roy. Society, Vol. B 76, 1905).
2) HERON-ALLEN, E., Bionomics, 1915, Pl. XV, fig. 18.

Conclusion.

Trimorphism is due to the peculiar origin of the embryons of Foraminifera. If the embryon has its origin in a zygote, it is very small; if it arises from a microspheric individual, then it is a larger one; it may derive from a megalospheric specimen, then it is the largest one; the last form gives rise to microspores.

Trimorphism is shown in different groups of Foraminifera, living and fossil. We came to the remarkable conclusion, that the whole embryon, and not only the first chamber, must be taken into consideration, when we analyse the trimorphism of a species.

V. *Trimorphism and systematics*

(with some remarks on the nomenclature of the shell-structure).

In my first Siboga-work (1927), as well as in other smaller articles I asserted my opinion about trimorphism with several examples. In most cases I found, that the characteristics of forma A_2 showed more resemblance with the microspheric generation (B), than those of A_1. The remarkable fact, that the microspheric form has more "primitive" characteristics than the megalospheric one (which was already known to students of Foraminifera), gave rise to the idea, that A_2 was also more "primitive" than A_1. CUSHMAN has worked out this idea in his beautiful systematical work, "The Foraminifera", 1928, Chapter X.

It is well known, that the microspheric generation of several species and genera shows in its growth a succession of different stages, each of which characterises the plan of growth of another genus, supposed to be more primitive. Several examples of this kind can be mentioned. CUSHMAN points out in two cases, that, when three of such stages are present in the microspheric generation, forma A_2 shows two of them in its development, forma A_1 only one, and that the "highest developed" plan of growth in the three forms is always that of A_1 and therefore is always present. This phenomenon has been stated already by GOES [1]). He figures megalospheric specimens of *Frondicularia alata*, the one showing true *Frondicularia*-development, the other beginning with a plan of growth, characteristic of *Vaginulina*. The microspheric form shows an even more typical *Vaginulina*-form.

These facts, pointed out by CUSHMAN, were stated once more in my studies on the species *Peneroplis pertusus*. Here especially the mouth of the shell shows in the microspheric generation three succeeding stages: 1, dendritic; 2, two rows of pores; 3, single row of pores. In the megalospheric specimens with small proloculum two kinds of mouths are met with at different ages of the individual: 1, dendritic; 2, two rows of pores. In the megalospheric generation with large proloculum only the dendritic form of aperture is met with in typical adult forms. I have tried to give a scheme of the gradual development of characteristics in the several stages, when dealing with the family of the PENEROPLIDAE.

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1) GOES, A., A synopsis of the arctic and Scandinavian recent marine Foraminifera hitherto discovered (Kongl. Svenska Acad. Handl., Stockholm, 1894, p. 6, fig. 1).

Now, with our recent knowledge of the real relations of the three forms in each species of Foraminifera, we may analyse their typical difference in development.

LISTER (l. c., 1897, p. 239) gives the following explanation of the dimorphism showed by the MILIOLIDAE.

"We find that while the asexually-produced megalospheric form has a direct development the sexually-produced microspheric form goes out of its way to repeat the arrangement characteristic of allied forms before it attains the arrangement proper to its own genus.

Is not this a particular instance of a phenomenon widely met with in higher forms of animals, in which the individuals, produced by budding, attain the adult structure by direct development, while those produced from the egg often develope by an indirect course, going out of their way to repeat lost features characteristic of the archaic forms of their race?"

Yet the author mentions the case of *Idalina antiqua* (which shows a fine example of trimorphism) and is right in his view, that "the exception does however appear to detract in some measure from the sharpness of the contrast in the mode of growth of the two forms, and, though I think without altogether annulling it, from the force of the explanation which I have offered".

As we have shown that typical trimorphism is met with in several groups of Foraminifera, we must search for another explanation of the facts and in this connection I may refer to the beautiful ideas of RHUMBLER, settled in his work on the Foraminifera of the Plankton-Expedition, 1910—1911, pp. 184—190. It was stated by this author, that the laws of capillarity interfer highly in the processes, which lead to the definite forming of the shell. The features of the successive chambers and the angles their walls form together are mainly due to internal circumstances in the protoplasm and to those in the surrounding medium.

So we can say that the shape of the foraminiferal shell (including later deposits of chalk or other material on the primary wall) depends on four factors:

I. Genetical factors;
II. Surface-tension of the protoplasm, ruled by the composition of the protoplasm;
III. Surface-tension of the surrounding medium, due to the characteristics of that medium;
IV. When the first wall, consisting mainly of organic material, has been formed, it is fastened by means of chalk-substance or foreign material (sand-grains f. i.) and then it may be thickened at the outer surface of the shell by secondary material; especially in the first formed chambers at the inner surface of the walls organic material may be laid down.

We will firstly deal with III.

As RHUMBLER pointed out already, the composition of the seawater, surrounding the growing individual influences the growth of the test. I can add many examples to those of RHUMBLER, when I look at the different shapes of the shells of the Foraminifera of the Zuiderzee, which are often so much modified, that they can scarcely be determined, especially in the northern part where the difference between ebb and flood with respect to the quantity of salt is large. I must however point out at once, that the smallness of the shells described in my work on the Protozoa of the Zuiderzee [1]) is mainly due to the high temperature of this sea (see RHUMBLER, l. c., 1910—11, pp. 200—209).

1) HOFKER, J., Flora en Fauna der Zuiderzee, Protozoen, 1922, p. 132.

RHUMBLER pointed out, that the first chambers of megalospheric young are growing out in quite different conditions, as they are formed within the microspheric parental protoplasm. It is therefore very obvious that these chambers do not follow the typical rules of growth (increasing of volume of chambers in a geometrical proportion) (see f. i. the initial set of chambers of *Orbitolites* and *Cycloclypeus*). The first whorl of chambers of microspheric forms on the contrary, developing free in the seawater, is not much in contradiction to this rule. But even the forming of the first chamber of the megalospheric generation in some respect is subject to the laws of surface-tension. As a larger volume of protoplasm has in the seawater a relatively smaller surface-tension than a smaller quantity and as there is always a tendency in liquid substances to obtain the smallest tension possible, there will be a high resistance of this tension against division of the protoplasm into smaller parts. So the first chambers of the buds will be as large as possible, and the surface-tension of the protoplasm of the microspheric (or small-loculated megalospheric) generation is a standard for the limit of division. Thus we can be sure of the fact, that the number of nuclei formed in the microspheric form stands in some relation with that tension. This surface-tension of the protoplasm however is a function of the surrounding medium too. When the density of the medium increases, the surface-tension of the protoplasm diminishes. If the animal would be capable to increase the density of its medium, this would make division more easy.

It seems to me, that in the case of *Polystomella crispa*, a typical species in seas with a high quantity of salt (it never occurs in aestuaries), the internal forces are large enough to conquer the surface-tension. But in aestuaries, in which, as in the Zuiderzee, the quantity of salt sinks to 1‰, this surface-tension must be much larger. Therefore we find, that in the Zuiderzee the individuals encystate before division, to form a surrounding, which is favourable for their division with respect to the surface-tension. [We may here also point to the peculiar double-walled chamber in *Cymbalopora bulloides* (see HERON-ALLEN, Bionomics, 1915), in which obviously sporulation takes place, and to the globular individuals of *Globigerina* (= *Orbulina*)].

Now we can fancy also, that the second megalospheric generation shows always a larger proloculum than the first one, because it must be seen in connection with the surface-tension. The different circumstances in which the two kinds of embryons arise, the difference in protoplasm, but even more the difference of season, in which they are formed (with its peculiar difference in density of the seawater) are the real influences, which determine the volume of the megalosphere. In the ocean f. i. the density of the water is low in summer, increases in autumn and decreases in spring.

In spring the first generation of megalospheric forms arises; the high density of the water is favourable for division of the protoplasm, so the microspheric form is not obliged to form a cyst and the division is easy: many, but consequently minute megalospheres are formed. In summer the second megalospheric generation begins. The density of the seawater is low, so the surface-tension of the protoplasm is large. It is obvious that the division is opposed by this difficulty and few divisions in the protoplasm give rise to large megalospheres. Therefore in summer megalospheric generations of the A_2-form occur.

But now interferes the forming of the chromidium, which, as I have pointed out in my

article on *Coscinodiscus biconicus* [1]), makes the protoplasm fit for rapid division (probably this will also be due to the lowering of the surface-tension of the protoplasm, which in this case is caused by internal factors).

Sure enough the growth of the later chambers is also a function of the surface-tension. Obviously the A_2-form shows chambers, which have other angles between their walls than the A_1-form has.

As in deeper seas the difference between the densities in the different seasons is not so large as at the surface or in neritic areas, the trimorphism of the Foraminifera, living in deep seas, is to be expected as not visible with respect to the growth of the chambers. Yet I have found several examples of deep-sea Foraminifera with typical trimorphism, so that the heterogamy must be considered as the primary factor. There is nothing astonishing in it, for, as WEISMANN and others have found, in the heterogamy of higher animals the seasonal factors are never so predominant as the genetic ones. But we may suggest that in some conditions the heterogamy is not visible in the characteristics of the shell. WINTER [2]) showed already, when dealing with dimorphism, that the nuclear dimorphism must be a very typical thing for all Foraminifera; but whether this trimorphism is also shown in the shells or not, is a question, which cannot sufficiently be answered in all cases, known hitherto; for, as we have shown above, the shells are dependant from other circumstances too.

Yet we can a priori suppose that the differences of the condition of the nuclei in the three forms may induce particularities to the shape of the shell. In microspheric as well as in megalospheric forms with small proloculum (A_1) we have seen, that the nuclear stages are nearly the the same. So we can take it for granted that the densities of the protoplasm in these two stages are nearly equal. The shape of the chambers, if outer circumstances would be the same, will be also identical. This is the reason why those stages resemble each other so much, as I had opportunity enough to state, when describing the different species of the Siboga-material or those from the senonian of Maestricht. The protoplasmic density of the second generation of megalospheric forms however is in a quite different condition, due to the forming of extranuclear chromatin in the protoplasm (chromidium). As all descriptions of other authors and of myself show, this chromatin, scattered in the protoplasm, is less liquid than the protoplasm itself. So the entire density of the protoplasm increases. But, if the density of the protoplasm increases, the surface-tension increases too. This will be of much influence on the shape of the chambers. This is the reason why this megalospheric generation (A_2) shows little conformity with the microspheric one, as I have shown already. RHUMBLER has also suggested that the nucleus influences the building of the shell (l. c., 1910—11, p. 295): "Der Schalenformungsmechanismus ist, soweit die Kernmasse dabei indirekt in Frage kommt, der Hauptsache nach keine Wärmekraftmaschine, sondern eine chemische Oberflächenenergiemaschine".

He also gives a very rational explanation of the difference between young and old microspheric and megalospheric generations, saying (p. 296):

"Es läszt sich darauf schlieszen, dasz die aus der Kopulation der Schwärmsporenkerne

1) HOFKER, J., Life-history of *Coscinodiscus biconicus* v. Breemen and the importance of expelled chromatin before reduction of chromosomes takes place (Tijdschr. Ned. Dierk. Ver., ser. 3, part. I, 1928, pp. 105—108).

2) WINTER, F. W., l. c., 1907, p. 104.

hervorgegangene Kernmenge der Mikrosphärischen anfänglich noch nicht die genau gleichen Plasma-Anomogenitäten induziert, wie späterhin, wenn sie unter Verteilung auf die Pluralnuclei älter geworden ist. Die Kernmasse als Stofflieferanten scheint mir einen Entwicklungsgang durchzumachen, der sie erst allmählich zu einer der Kernmasse der Makrosphärischen durchaus konformen Lieferungs- und Wirkungsweise hinführt, sobald nur erst der mikrosphärische Weichkörper die Gröszenstufe der Makrosphären erreicht hat".

IV. Deposition of organic matter at the inner side of the walls of the chambers gives no alteration of the outer aspect of the shell; therefore only secondary deposits of chalk at the outer surface remain to be considered.

RHUMBLER has pointed out that the chalk-deposits on the shell are inversely proportional to the quantity of salt, dissolved in the seawater. HERON-ALLEN (Bionomics, 1915, pp. 261—263) showed that if specimens of *Massilina secans* were cultivated in a tank, in which the quantity of chalk was enlarged, there arised the well known varieties *denticulata*, *tenuistriata* and *obliquistriata*. So secondary chalk-deposits have a very doubtful value as specific characteristics. This statement must be considered as a very important one. We have found already some beautiful examples of the more than doubtful value of the secondary chalk-skeleton, dealing with the different forms of the family of the TINOPORIDAE. I have shown there (Part I of this work, pp. 3—20) that the three forms of a single species show very great differences with respect to their chalk-columns and spines. Fossil forms, such as *Orbitolites*, *Lepidocyclina*, etc. belong evidently to the same group of Foraminifera, and equally show a high variation of their secondary chalk-deposits. So it is to fear, that different forms of a species of these fossil groups will show different development of their pillars, columns and even spines. Yet several authors have based new species only on differences with respect to the development of secondary chalk-material. All such species have to be revised accurately, dropping all characteristics of secondary chalk-deposits.

The genetic characteristics remain to be discussed. They show the real generic and specific characteristics, f. i. the arrangement of the chambers, together with the shape of the canals. But even the habitus of the mouth or mouths of the last chamber (and consequently the foramina between the succeeding chambers) and the pores are only subject to the influence of a special part of the protoplasm, which is stainable in a particular way and has been named by RHUMBLER "Mündungsplasma".

As those typical features as apertures, foramina and pores are of great systematical importance, it is a matter of fact that their nomenclature must be fixed. Several authors however use names, different from those, I mentioned here. So it is here the place to discuss this matter.

In Part I of the Siboga-Foraminifera I have already given a short definition: Foramina are the passages between succeeding chambers (I made a difference between primary and secondary foramina); apertures are the foramina of the last formed chamber, forming the way for the protoplasm to get out from the shell; pores are the fine perforations of the walls of perforate shells. Mostly they are very narrow; in cases, in which larger pores occur, it is very probable that they are openings, made for spores to leave the parent-shell. The typical pores (f. i. pores of ROTALIIDAE or NUMMULITIDAE) may have especially to do with respiration. Succeeding

chambers never communicate by pores. In those cases, in which chambers communicate by pores, they are not succeeding (*Orbitoides*, *Lepidocyclina*, etc.). All other names must be eliminated from literature. WAYLAND VAUGHAN says that my names pores and foramina are of "more than doubtful validity" in (CUSHMAN, Foraminifera, 1928, p. 348), though I do not know why. D'ORBIGNY [1]) divided his "Cephalopoda" into Siphonifères, with a tubular siphon traversing the series of chambers, and in Foraminifères, in which the chambers communicate by "foramina". So these communications between succeeding chambers must be called foramina and not otherwise. In the classic work of SCHULTZE [2]) the fine canals in the walls are called "pores" and therefore this name must be used here also. Why VAUGHAN and other specialists in ORBITOIDIDAE have chosen two special names for the very same thing, I do not know: they call it apertures or pores (which will give confusion) and the pores are named "cribriform perforations" (why?).

The publication of CALKINS (Biology of Protozoa, 1926, p. 130) gives cause to further contradiction, as he says: "Except for a single mouth opening such limestone shells may form an unbroken wall about the organism (imperforate) or they may be perforated by myriads of minute pores (foramina) through which the pseudopodia pass to the outside, a condition which gave rise to the name Foraminifera".

As we have seen above, this opinion is an erroneous one. It is also met with on p. 333 of the same work: "In the perforate types pseudopodia are also protruded through the finer pores (foramina) of the shell".

LÜHE [3]) gives a much better definition: He mentions the foramina of the last chamber as "Mündung", in the same way as we have called it aperture. The openings between succeeding chambers, the former apertures, have not got a special name; the finer openings of the perforate shells are called "Wandporen". CARPENTER [4]) also describes apertures and pores in the same way: "For in these (Perforata) the apertures in the septal planes by which the chambers communicate with each other and by which the special communication is established between the last chamber and the exterior, are so much narrowed that they are sometimes not easy to be discovered; but, on the other hand, the lateral walls of the chambers are everywhere perforated, more or less closely, with pores for the exit of pseudopodia".

RHUMBLER (l. c., 1910—11, p. 121) says: "Es lassen sich zwei Arten von Öffnungen in der Schalenwand unterscheiden, einmal die allen Foraminiferen zukommende "Schalenmündung" und dann die auf die perforaten Formen beschränkten "Wandporen".

So we come to the conclusion, that the mouth or mouths of the last chamber (or chambers) of the shell must be called "apertures" or "mouths"; the passages between succeeding chambers must be named "foramina" according to D'ORBIGNY (they are the old apertures of the shell, but in many cases they have altered their original form); the fine canals, running from the lumen of the chamber straight to the surface, are to be called "pores".

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1) D'ORBIGNY, A., Tableau méthodique de la classe des Céphalopodes (Annales des Sciences Naturelles, vol. 7, 1826).

2) SCHULTZE, M. S., Über den Organismus der Polythalamien (Leipzig, 1854, p. 13).

3) LÜHE, M., Handbuch der Morphologie der wirbellosen Tiere (Protozoa vol. 1, 1913, p. 185).

4) CARPENTER, W. B., PARKER and JONES, Introduction to the study of the Foraminifera (London 1862, p. 31).

Conclusions:

A specific name may never be based upon:

a) secondary chalk-substance (pillars, protuberances, tubercules, etc.);

b) form and size of the embryonic apparatus of the megalospheric generation, if the student does not know all about the different megalospheric generations in the species and their relationships;

c) differences in the shape and measures of the chambers.

No student in living or fossil Foraminifera must be content, when describing Foraminifera, if he describes not at least three forms of a single species.

Family ASTRORHIZIDAE.

This family belongs to the most badly known of the Foraminifera. Though some forms, such as *Astrorhiza* and *Rhabdammina* are found in nearly all seas of tolerable depth, a study of the protoplasm has never been made. As the shell of the different species of this family is very friable, entire individuals have been studied very rarely. This was the reason why more than once a part of a species has been described as a species.

Studies on the bionomics of these species are not to be found in literature, so that a really good system cannot be established. I believe that forms as *Vanhoeffenella* and *Crithionina* may be reproductive stages of other Foraminifera, etc.

Description:

The test may be free in all cases and consists of a central chamber from which are radiating tubular, sometimes branching, outgrowths. Wall consisting of a chitinous layer or a thick agglutination of foreign material of quite the same consistance as the walls of the cysts of *Miliolina* or *Eponides* described in our Introduction. Apertures are present, at the ends of the tubes or in the walls.

In the Siboga-material only two genera with one single species each have been found, especially from deep soundings. It is very probable that in tropical seas representatives of the ASTRORHIZIDAE are very rare, as most species are typical for arctic, cold seas. Only in deep water, which temperature is equally low, some forms may be found in the tropics. CUSHMAN, in his work on the Foraminifera of the Philippine and adjacent seas [1]), mentions the same two genera, which I found in the Siboga-material, viz. *Astrorhiza* and *Rhabdammina*. From the genus *Astrorhiza* he describes three species, *A. angulosa*, *A. granulosa* and *A. agglutinata*, while I found only a single specimen of *A. agglutinata*. The genus *Rhabdammina* is represented in CUSHMAN's enumeration by the species and varieties *R. abyssorum*, *R. abyssorum* var. *radiata*, *R. irregularis*, *R. discreta* and *R. linearis*. I have found *R. abyssorum*, *R. abyssorum* var. *radiata* and *R. irregularis*, and I believe them to be different parts of a single species.

Rhabdammina irregularis, *R. abyssorum* and *Astrorhiza agglutinata* were the only species, CUSHMAN found in the Philippines in some abundance.

In his Handbook [2]) he says, dealing with *Astrorhiza* and *Rhabdammina*: "most of the species are characteristic of cool water condition and temperature is more of a control than depth".

1) CUSHMAN, J. A., Bull. 100, U. S. Nat. Mus., vol. 4, 1921, pp. 35—40.
2) CUSHMAN, J. A., The Foraminifera (Sharon, 1928, p. 64).

I. Genus **Astrorhiza**.

Test free, flattened or lenticular, or tubular. Some forms are stellate, others (which may be doubtful, as they may belong in reality to other genera) are cylindrical. It is very probable that *Astrorhiza* forms a single genus together with *Rhabdammina*, as the differences of the two genera are very uncertain. In both genera the central portion of the shell communicates with the outer world by long, often bifurcating stolons. Walls consisting of foreign material, and very thick, with more or less organic cement.

1. *Astrorhiza arenaria*, var. *agglutinata* (Cushman). Plate XLII, figs. 1—4, Pl. XLIV, fig. 1.

Astrorhiza agglutinata Cushman, U. S. Nat. Mus., Bull. 100, 1921, vol. 4, p. 36.

Cushman, in his paper on the Foraminifera of the Philippine and adjacent seas, describes this form in the following way:

"Test irregular in form, flattened, wall composed of agglutinated fragments of other Foraminifera, at the type station mainly Globigerinidae; aperture near the border of the test. Diameter up to 5 mm. In its irregular form the species reminds one of *A. arenaria*".

Only very few specimens of *A. agglutinata* were gathered by the Siboga-Expeditiön at the stations:

Stat. 300. 10° 48′.6 S.. 123° 23′.1 E., depth 918 m.
Stat. 318. 6° 36′.5 S., 114° 55′.5 E., depth 88 m.

At first its irregular form and dark coloured, smooth surface suggested the idea, that the specimen belonged to *A. arenaria*. As the foraminiferal shells, building up the wall, were not to be seen outside, only the section made them visible. Only the inner layers of the thick wall were mainly composed of shells of Foraminifera (*Globigerina*, *Textularia*) and some Radiolaria. The surface of the shell consists of a very dark brown organic material.

The protoplasm of a part of the individual was studied; it showed the normal vacuolated structure, and also a nucleus was observed.

This form has exclusively been met with in the East-Indian areas.

The only difference between *A. arenaria* and Cushman's *A. agglutinata* is the composition of the test. I believe this difference not to be so important, that a new species may be based upon it. So I called it a variety, due to special circumstances.

The specimen found at station 300 was a very complete one, as several stolons were even longer than the diameter of the central part of the shell. These stolons are already known through the investigations of other authors, but it stroke me that the finer stolons were nearly identical with some specimens of *Rhabdammina algaeformis*, found in the same gathering. As very few material was present, I can only suggest an alliance between these two species and later investigations must solve this question. I have figured this beautiful specimen on Plate XLIV, fig. 1.

II. Genus Rhabdammina.

Test free, radiate or subcylindrical. Stolons often branching; walls firmly cemented, composed of sandgrains or other foreign bodies, with more or less organic material, especially in the interior. Yellowish-brown. Open ends of the tubes serving as apertures. Cool water species.

1. *Rhabdammina abyssorum* W. B. Carpenter. Pl. XLII, figs. 5—11; Pl. XLIII, figs. 3, 4 and 6.

Rhabdammina abyssorum M. Sars, Förh. Vid. Selsk. Christiania, 1868, p. 248 (nomen nudum); W. B. CARPENTER, Ann. Mag. Nat. Hist., ser. 4, vol. 4, 1869, p. 288, Proc. Roy. Soc. London, vol. 18, 1869, p. 60. For other literature see: CUSHMAN, J. A., The Foraminifera of the Atlantic Ocean, Pt. I, Astrorhizidae, U. S. Nat. Mus., Bull. 104, 1918 and: CUSHMAN, J. A., U. S. Nat. Mus., Bull. 100, vol. 4, 1921, p. 36—37, Pl. 1, fig. 2.

Rhabdammina abyssorum var. *robusta* Goës, Köngl. Svensk. Vet. Akad. Handl., vol. 19. n° 4, 1882, p. 143, Pl. 12, figs. 430, 431.

Astrorhiza abyssorum Eimer et Fickert, Zeitschr. Wiss. Zool., vol. 65, 1899, p. 666.

Rhabdammina abyssorum W. B. Carpenter, var. *radiata* Cushman, Proc. U. S. Nat. Mus., vol. 51, 1917, p. 652.

Rhabdammina irregularis W. B. Carpenter, Proc. Roy. Soc. London, vol. 18, 1869, p. 60 H. B. BRADY, Rep. Voy. Challenger, Zoology, vol. 9, 1884, p. 268, Pl. 21. fig. 9; CUSHMAN, U. S. Nat. Mus., Bull. 100, vol. 4, 1921, p. 38, Pl. 1, fig. 5.

Stat. 88. 0° 34′.6 N., 119° 8′.5 E., depth 1302 m.; 2 specimens.
Stat. 211. 5° 40′.7 S., 120° 45′.5 E., depth 1158 m.; ± 25 specimens.
Stat. 221. 6° 24′ S., 124° 39′ E., depth 2798 m.; it was a 5 cm. thick layer of brown mud, uppermost with Foraminifera; abundant.
Stat. 223. 5° 44′.7 S., 126° 27′.3 E., depth 4391 m.; a 14 cm. thick layer of brown and black mud; few specimens.

Description:

Test free, probably sunk beneath the muddy surface of the sea-bottom, consisting of a central subglobular chamber with typically three, in the variety *radiata* with four to eight arms; in the last case not always in a single plane. The arms in younger specimens remain simple, but afterwards attain a length of about three to four c. m. each, and often fork at the ends. These forks remain short and end with circular openings; in this way forming the apertures of the shell. It is probable that these ends of the arms open into the water, so that the pseudopodia can gather diatoms and other food particles from the muddy surface of the bottom.

The individuals of almost all samples have lost the forking ends of the branches, as these branches are very thin and fragile. Thus in one sample occur the centres of the shells together with the broken off arms, by other authors called *R. irregularis*.

Wall of mostly very fine sandgrains, firmly cemented, with a reddish-brown cement in some individuals, with an often much darker coloured cement in tropical seas. Interior of the test smoothed by a fine layer of

organic substance; exterior in some cases very rough, always distinctly showing the sandgrains. In some specimens the walls lack any secondary structure, but in others there are slight constrictions. Diameter of an entire individual up to 70 mm.

The material has been examined by means of the usual methods: by making slides the internal structure was shown, and complete specimens were mounted in canadabalsam. Of some few specimens, preserved in alcohol, the protoplasm was studied. As the very hard test could not be removed from the protoplasmatic body, as has been described by RHUMBLER [1]), LÜCKE [2]) and HIRSCH [3]) in the case of *Saccammina*, the specimens first have been macerated a little bit with the aid of hydrochloric acid and, after being stained with iron-haematoxylin, mounted in toto in canadabalsam. As there were no data about the protoplasmatic structure of *Rhabdammina*, this study was of some importance, for it showed the typical constitution of the foraminiferal protoplasm; it is filled up with chromatic material and with food-particles, consisting mainly of diatoms and detritus.

In the four samples, containing *Rhabdamminae*, the two forms occurred, which have been described by BRADY (l. c. p. 267) under the name *Rhabdammina abyssorum*: the typical specimens and the "variety", called by CARPENTER *R. irregularis*. The latter has been distinguished by later authors as a different species and CUSHMAN (l. c., 1921, p. 37) has added to these two forms a third, the variety *radiata* mentioned above.

There is some probability that the form *radiata* is a distinct variety, as it has been gathered only in Asiatic seas. The normal form *R. abyssorum* however, has also been found at these localities. The only difference between *R. abyssorum* and *R. abyssorum* var. *radiata* is the higher development of branching of the latter species and the tapering form of the branches. CUSHMAN says that the arms show annular constrictions. It is very true that most individuals from the North Atlantic do not possess these constrictions; but I believe that they are mainly due to the other life circumstances and the other material used for the construction of their shells. It is a very remarkable fact that in all samples I examined, from the West-Indies, from the North Atlantic and from the East-Indian Archipelago, both species *R. abyssorum* and *R. irregularis* occurred. At first I was inclined to believe, that they were different generations of the same species, but my friend C. v. RIJSINGE suggested that *R. irregularis* was nothing else than the forking ends of the branches of *R. abyssorum*. I believe now he is quite right, as these very long, but fragile branches in a deep-sea gathering never will reach the surface undisturbed. Afterwards we were so lucky to find a specimen of *R. radiata* with one of the branches forking and this "forking branch differs in no respect from a typical *R. irregularis*". One of the most striking features of the latter is the fact that generally one of the three branches is longer than the other two; these two form an angle of about 60 degrees, while the two other angles with the third branch are subsequently obtuse. The shape of the whole specimer is that of an Y.

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1) RHUMBLER, L., *Saccammina sphaerica* M. Sars (Zeitschr. f. wiss. Zool., vol. 57, 1894).
2) LÜCKE, F., *Saccammina sphaerica* M. Sars (Dissertation, Kiel, 1910).
3) HIRSCH, E., Die Entwicklungsgeschichte von *Saccammina* (Arch. f. Protistenkunde, vol. 27, 1912).

It is therefore that I thought it better to drop the name *R. irregularis* and to give a new definition of the species *R. abyssorum* (see the "description" at the beginning of this discussion), though it may be possible that a variety *R. abyssorum* var. *radiata* exists.

A remarkable difference between the typical central part of the shell of *R. abyssorum* and the forking arms can be stated, when examining longitudinal sections. It has been suggested by KEMNA [1]) that *R. abyssorum*, when young, consists only of the central chamber. Growing larger, the protoplasm forms no other chambers as other Foraminifera do, but forms tubes, the most primitive modus of growing of the shell. If this is really the case, one must find, when sectioning the fullgrown shells, that at the base the arms show a thickening, as they are built on the edges of the foramina of the young shell, which is indeed to be seen. With the growth of the protoplasm, the branches fork gradually to procure to the protoplasm new roads to stream through. Therefore there cannot be found any thickening of the walls at the places of forking, which is indeed to be seen, when examining thin slides.

1) KEMNA, A., Les caractères structuraux de la coquille de foraminifères flottants. Caractère naturel de la division des foraminifères en Perforés et Imperforés (Bull. soc. malacologique et zoologique belgique; Bruxelles, 1904, p. 10). See also: RHUMBLER, Die Foraminiferen (Thalamophoren) der Plankton-Expedition (vol. II, 1913, p. 359).

Family RHIZAMMINIDAE.

CUSHMAN [1]) describes this family as follows: "Test consisting of a tubular chamber open at both ends; wall with a chitinous lining and exterior of agglutinated foreign material, arenaceous grains, sponge spicules or other Foraminifera; aperture formed by the open ends of the tubes".

This description must, however, be altered with respect to the genus *Bathysiphon*, or *Bathysiphon* must be removed from this family, as I found in material from the arctic seas, that some forms of *Bathysiphon* possess a secondary wall, closing one of the ends of the tube, and as I could state, that *Bathysiphon rufus* begins as *Ammolagena clavata*, which is also closed at one of its ends. Secondly it is very probable, that the genus *Rhizammina* consists of attached forms, or of the distal branches of forms, which are known as other species f.i. *Astrorhiza*. In this connection I can quote CUSHMAN's [2]) words, when he deals with *Rhizammina*: "There is a possibility that the species of this genus have been broken in dredging, and that when perfect they may be attached and not open at the base".

I believe that even the existence of a real genus *Marsipella* is doubtful, as I found some relation with *Bathysiphon*.

Very little is known about the protoplasm, the knowledge of which would be very desirable. The Siboga-material did not give much data in this respect.

I. Genus **Marsipella.**

Test free and tubular, open at both ends, sometimes recurved at the ends, but mostly fusiform. Wall thin, consisting mainly of sponge spicules, which are arranged in the axis of the test. The middle (and older) part of the shell is covered with a layer of agglutinated material, sandgrains or irregularly arranged sponge spicules.

Most species are found in cool water.

1. *Marsipella elongata* Norman. Pl. XLV, figs. 15*a* and *b*.

Marsipella elongata Norman, Ann. Mag. Nat. Hist., ser. 5, vol. 1, 1878, p. 281, Pl. 16, fig. 7; CARPENTER, The microscope, ed. 6, 1881, p. 261, figs. 320*d*—*f*; BRADY, H. B., Rep. Voy. Challenger, Zool., vol. 9, 1884, p. 265, Pl. 24, figs. 10—19; CUSHMAN, Bull. 104, U. S. Nat. Mus., 1918, p. 23, Pl. 8, figs. 2, 3.

1) CUSHMAN, J. A., The Foraminifera (1928, p. 66).
2) ——, l. c., 1928, p. 67.

The species was only found at one single station:

Stat. 221. 6° 24′ S., 124° 39′ E., depth 2798—3112 m., ± 10 specimens.

Description, given by CUSHMAN:

"Test elongate, somewhat fusiform, irregularly curved, thickest in the central portion and gradually tapering towards the ends; walls composed of sponge spicules with the central thicker portion covered with sandgrains, spicules almost exclusively forming the ends of the tubes, laid together lengthwise and cemented firmly in place; aperture at the ends of the tube. Length, up to 8 mm.".

It seems to me, that at the beginning the shell only consists of the lengthwise arranged sponge spicules and that afterwards the older parts of the test are covered with other foreign material; hence the ends show only the spicules.

Most specimens of the Siboga-material are straight and have a length of 4—5 mm.

The species is not recorded by CUSHMAN from the North Pacific Ocean, nor has he found it in the Philippines.

2. *Marsipella cylindrica* H. B. Brady.

Marsipella cylindrica H. B. Brady, Proc. Roy. Soc. Edinburgh, vol. 11, 1882, p. 714; CUSHMAN, Bull. 71, U. S. Nat. Mus., Pt. I, p. 30, figs. 15, 16.

Only one single specimen was observed at station 227.

II. Genus **Bathysiphon** M. Sars.

Test always cylindrical and tapering (though sometimes very little), but in older individuals only cylindrical, the first part being always broken off. Wall composed of sand grains or (and) sponge spicules, which are cemented together by organic material. The latter forms in most cases the larger part of the shell. Most species show typical transversely arranged rings, due to periodical growth.

The systematical arrangement of the species is only based upon characteristics, such as colour, composition of the wall and tapering of the shell, which are all subject to the outer circumstances. Hence it is very difficult to determine the different species.

Specimens from the gulf of Gascogne and adjacent seas were described very accurately by DE FOLIN [1]). Some additions were given by CUSHMAN, who gave also an account in 1921 [2]) on the genus from the Philippines. Some other species have been described by HERON-ALLEN and EARLAND [3]) and by CUSHMAN in 1927 [4]).

In the Siboga-material occur four or five "species". In reality they must be considered as three different species, probably as only two.

1) FOLIN, L. DE, Les Bathysiphons; premières pages d'une monographie du genre (Actes de la société Linnéenne de Bordeaux, vol. XL, (ser. 4, vol. X), 1886. pp. 271—289, Pl. V—VIII).

2) CUSHMAN, J. A., Foraminifera of the Philippine and adjacent seas (U. S. Nat. Mus., Bull. 100, vol. 4, 1921, pp. 41—45).

3) HERON-ALLEN, E. and EARLAND, A., Foraminifera, Clare Island Survey (Proc. Roy. Irish Academy, vol. 31, Pt. 64, 1913, p. 38).

4) CUSHMAN, J. A., Foraminifera from the west coast of America (Bull. Scripps Institution of Oceanography, La Jolla, Techn. Ser., vol. I, 1927).

1. *Bathysiphon rufus* de Folin. Pl. XLV, figs. 1—14; Pl. XLIII, figs. 1, 5.

Bathysiphon rufum de Folin, Actes Soc. Linn. de Bordeaux, vol. 40, 1886, p. 283, Pl. 6, figs. 8*a—c*; FLINT, Rep. U. S. Nat. Mus., 1897 (1899), p. 267, Pl. 7; CUSHMAN, Bull. 71, U. S. Nat. Mus., pt. I, 1910, p. 32, fig. 22; CUSHMAN, Bull. 104, U. S. Nat. Mus., pt. I, 1918, p. 29; CUSHMAN, Bull. 100, U. S. Nat. Mus., vol. 4, 1921, p. 42, Pl. 2, fig. 2; CUSHMAN, Bull. Scripps Inst., La Jolla, vol. 1, 1927, p. 129.

Bathysiphon rufescens Cushman, Proc. U. S. Nat. Mus., vol. 51, 1917, p. 651; CUSHMAN, Bull. 100, U. S. Nat. Mus., vol. 4, 1921, p. 43, Pl. 2, figs. 3*a*, *b*.

Bathysiphon arenacea Cushman, Bull. Scripps Inst., La Jolla, vol. 1, 1927, p. 129, Pl. 1, fig. 2.

Girvanella vagans (H. B. Brady) Rhumbler, Foram. Plankton Exped., pt. I, 1911, Pl. 4, figs. 1, 2; pt. II, 1913, p. 413; CUSHMAN, U. S. Nat. Mus., Bull. 104, 1918, pt. I, p. 91, Pl. 35, figs. 4, 5; Pl. 36, fig. 1.

Ammolagena clavata (Parker et Jones) Eimer et Fickert, Zeitschr. wiss. Zool., vol. 65, 1899, p. 673; CUSHMAN, U. S. Nat. Mus., Bull. 104, 1918, pt. I, pp. 89—90, Pl. 34, figs. 2—5; Pl. 35, figs. 1—3.

Glomospira gordialis (Jones et Parker) Rzehak, Verh. k. k. geol. Reichsanstalt, 1888, p. 191; CUSHMAN, U. S. Nat. Mus., Bull. 104, 1918, pt. I, p. 99, Pl. 36, figs. 7—9.

This species occurred only in the dredging at a single station, viz.:

Stat. 223. 5° 44'.7 S., 126° 27'.3 E., depth 4391 m.

6 specimens of the typical form of *B. rufus*, ± 20 with the habitus of *B. rufescens* and a few specimens of *B. arenacea* were met with.

Description of the species:

Wall in younger specimens polished and showing annular lines of growth and depressed areas. These specimens are "somewhat curved, decidedly tapering from the small initial end to the much larger last-developed portion". Older individuals, from which generally the initial part has been broken off, are straight; wall not polished, surface dull. The most highly developed specimens have a very thick wall.

The wall of all individuals is mainly composed of sand grains, even in the youngest individuals. These sand grains are heaped together in a very peculiar way. Most of them have a somewhat flattened shape. Those, forming the inner part of the wall, are situated with their long axes perpendicular to the length of the shell. Those forming the middle part of the wall are arranged so that their axes form an angle of about 80° backwards, and so on. As these grains have often small dimensions, this arrangement is not always obvious; the outer layer of granules, which have larger dimensions than those of the inner one, are directed even parallel to the axis of the entire individual and it is this fact which causes the polish of the shell. As the organic material (called by DE FOLIN "la pâte" and which is of a yellowish brown colour) especially forms the greater part of the external layers of the shell, it gives the entire individual its typical brownish colour. The last-formed part of the shell, the apertural end, however, lacks this external layer of mainly organic material and keeps therefore a grey colour. This end of the shell shows a conical shape, due to the direction of the layers of sand grains. DE FOLIN describes and figures sponge spicules in the walls of *B. rufus*. I do not know if his observation was correct; I can only state, that, though the protoplasm was filled up with spicules and Radiolaria, they were never found in the wall. The peculiar material of the wall in this way was not at all due to the lack of spicules, as one would suggest.

The initial ends, even of the smallest individuals, were always broken off. In the same sample occurred some individuals belonging to forms, which one would call "*Webbina*" or something like that. These individuals showed the same shell-structure as this *Bathysiphon* and their sipho was always broken off. Are these individuals really young *Bathysiphon*? As I may point out here, this is only a suggestion, though a very probable one. I can also mention here the fact, that in a sample from the gulf of Mexico were found together the same *Bathysiphon* and this "*Webbina*" (now called *Ammolagena clavata*) in nearly equal abundance.

In our sample 223 I found also some specimens of the peculiar organism called *Girvanella vagans* (H. B. Brady). As we know, the initial part of this form also shows an oval proloculum. The texture of the shell is quite like that of *Ammolagena* and consequently like that of *Bathysiphon rufus*. Probably *Girvanella vagans* is nothing else than a second form of this *Bathysiphon*.

In this remarkable sample 223 was also found an individual of *Glomospira gordialis* (Jones et Parker). I do not know whether all specimens, known as *Glomospira*, show the same habitus, but this individual was a typical microspheric one, in the beginning planospiral; later on the curls showed a more irregular plane of growth, the last coil was not curled at all, but stretched out, and its wall was identical with that of the larger forms of *Bathysiphon rufus*, called by CUSHMAN *B. rufescens*. That the typical *Glomospira gordialis*, even with respect to the state of the nucleus, is microspheric was shown by SCHAUDINN [1]), as he observed, that it formed 80—100 embryons, which can only (in such a great number) be the case in a microspheric specimen. The walls of the young are composed of sand grains within the protoplasm of the parent.

When my suggestions as I have exposed them here are right, *Bathysiphon rufus* shows a typical trimorphism:

Forma A_1. Initial part of the shell an elongate oval proloculum, followed by a long irregular second chamber, which at first is attached to molluscs or something else, afterwards becomes free and than probably is situated between the loose material of the sea-bottom. The first part of the organism is called in literature *Girvanella vagans* (H. B. Brady), the second, free stage, when broken off (as always is the case with these deep-sea individuals), is known as *Bathysiphon rufus* de Folin or *B. rufescens* Cushman.

Forma A_2. Initial part beginning with an attached proloculum of oval shape, sometimes pyriform, the basal portion flattened and with a very thin wall. The second chamber is tubular, of nearly uniform diameter, in the beginning attached, later on becoming free and then giving rise to what is called *Bathysiphon rufus* de Folin. The initial part is known as *Ammolagena clavata* (Jones et Parker).

Forma B. Initial part beginning with a free, very narrow proloculum, followed by a close-coiled spiral in a single plane, but afterwards this spiral becomes irregular. This stage is known as some forms of *Glomospira gordialis* (Jones et Parker). The last coil is stretched out, generally directed straight to the plane of the first spiral. The later part of the shell is known in literature as *Bathysiphon rufescens* Cushman or *B. arenaria* Cushman.

1) SCHAUDINN, F., Die Fortpflanzung der Foraminiferen und eine neue Art der Kernvermehrung (Biol. Centralbl., vol. 14, 1894, p. 97).

2. *Bathysiphon filiformis* G. O. Sars. Pl. XLVI, fig. 8; Pl. XLVII, figs. 5, 6, 10 and 11.

Bathysiphon filiformis G. O. Sars, Forh. Vid. Selsk. Christ., 1871 (1872), p. 251; NORMAN, Rep. Brit. Assoc., 1880, p. 389; H. B. BRADY, Rep. Voy. Challenger, Zool., vol. 9, 1884, p. 248, Pl. 26, figs. 15—20; CUSHMAN, Bull. 71, U. S. Nat. Mus., pt. I, 1910, p. 31, text-figs. 17—21; Bull. 104, U. S. Nat. Mus., pt. I, 1918, p. 27, Pl. 11, figs. 4—5; Bull. 100, vol. 4, U. S. Nat. Mus., 1921, p. 41, Pl. 2, fig. 1; DE FOLIN, Actes Soc. Linn. de Bordeaux, vol. XL, ser. 4, vol. X, 1886, p. 279, Pl. VI, figs. 4*a*—*e*.

Stat. 178. 2° 40′ S., 128° 37′.5 E., depth 835 m., abundant.
Stat. 211. 5° 40′.7 S., 120° 45′.5 E., depth 1158 m., few.
Stat. 221. 6° 24′ S., 124° 39′ E., depth 2798 m., abundant.
Stat. 223. 5° 44′.7 S., 126° 27′.3 E., depth 4391 m., a single large specimen.
Stat. 271. 5° 46′.7 S., 134° 0′ E., depth 1788 m., 15 specimens of different size.

Description:

Test free, but probably attached in youth, cylindrical, tapering very slightly, so that shorter pieces of the tubes are of nearly uniform diameter; in the first (older) part the test is more curved, than in its younger. Young specimens have a diameter of about 0.75 mm., which can increase towards 2 mm. in the Siboga-material. CUSHMAN gives a diameter up to 4 mm. Length up to 60 mm. The apertural end shows a half-globular shape, at the end lies the aperture.

The wall is unvariably composed of sponge spicules. In the inner layer of the wall these spicules are arranged closely together, transversely to the long axis of the tube, tangentially to the inner surface. Thus a solid inner layer is formed. It is followed by a thick outer layer with very irregularly placed spicules, cemented by a fine amorphous material, uncoloured except for the outmost sheath, which, in older specimens, is of a dull black, brown or even yellowish colour. This colour is probably due to the pigmentation of the surrounding mud. There is but little cement, the greater part of the shell is built up by spicules. In younger specimens the outer layer of the shell is covered with an complete film of organic material. Older specimens often show spicules projecting out of the surface in all directions. They never show a polished surface. The shell is delicately built and friable.

Two forms, generally occurring together in the same sample, could be traced. The one has a white colour, and the surface shows but very few annular rings. Here and there dark brown spots and rings are to be seen at the surface. The internal layer of tangential spicules forms about a quarter of the total thickness of the wall. The second form has an equally distributed greyish yellow colour, which is due to a very thin but always present sheath of organic material at the very surface of the wall. The test shows many annular rings. The layer of tangential spicules has a thickness of only two or three spicules, and at the surface of the wall the spicules are arranged even more tangentially.

When we observed these peculiar animals in sections, we were always struck by the fact, that the construction of the walls is very much like that of some species of the genus *Marsipella* H. B. Brady. When the external layer of spicules is not considered *Bathysiphon filiformis* would be a large *Marsipella spiralis* Heron-Allen et Earland. In this connection I mention here that CUSHMAN (l. c., 1921, p. 27) describes DE FOLIN's *Bathysiphon echinata* as a *Marsipella*. It is possible that *Marsipella* and *Bathysiphon* are very closely allied genera, if not identical, *Marsipella* being the young of *Bathysiphon*. There is, however, another genus, that I would

mention in this connection, e. g. *Haliphysema* Bowerbank. The expanded basal portion of these forms is very like that of *Sagenina* and of *Ammolagena*, which, as we have suggested, were but young *Bathysiphon rufus*. The circular aperture, surrounded by a crown of erect spicules will very probably also occur in living *Bathysiphon*. *Haliphysema Tumanowiczii* Bowerbank will be nothing else than a shallow water *Bathysiphon*.

3. *Bathysiphon flavidus* de Folin. Pl. XLVI, fig. 3; Pl. XLVII, figs. 7, 8, 9, 12.

Bathysiphon flavidum de Folin, Actes Soc. Linn. de Bordeaux, vol. XL, (ser. 4, vol. X), 1886, p. 279, Pl. 6, figs. 5*a—c*; CUSHMAN, U. S. Nat. Mus., Bull. 100, vol. 4, 1921, p. 44.
Bathysiphon flavidus de Folin, var. *giganteus* Cushman, U. S. Nat. Mus., Bull. 100, vol. 4, 1921, p. 44, Pl. 2, figs. 4*a*, *b*.

Beautiful specimens of this species occurred at the following stations:

Stat. 210. 5° 28′ S., 121° 23′.5 E., depth 2218 m.
Stat. 211. 5° 40′.7 S., 120° 45′.5 E., depth 1158 m.

Description:

Test elongate, cylindrical, nearly straight, marked by many annular areas of growth. The wall of some specimens, which have a reddish orange or brown colour, is polished. Other, somewhat thicker specimens, always of a yellowish colour, are dull and most of them larger than the former. CUSHMAN described them as the variety *giganteus*. As sections have shown me that this difference is due to the smaller quantity of organic material in the external layers of the shell of the var. *giganteus*, I believe that we must not consider these specimens as a variety. It is however possible, that they are different forms of the same species.

The wall is composed merely of sponge spicules, but with a large quantity of organic, brown coloured material. The arrangement of the spicules is quite different from that in *B. filiformis*, but is much like that in *B. rufus*. The material is only another one. Yet, this difference may be due to outer circumstances and so it is possible, that *B. rufus* and *B. flavidus* are but varieties.

An internal layer of spicules, as in *B. filiformis*, is not to be found. At the inner margin the spicules are generally irregularly arranged. They are cemented with brown cement in the older parts of the shell, but the younger part lacks this colour. Only the external layer of the shell shows a very particular arrangement of the spicules. The organic material forms the greater part of it. In this layer all spicules are arranged nearly parallel to the surface and in the axis of the shell. Those of the next internal layer are directed with a sharp angle to this surface. The large quantity of organic material causes the brown colour of the shell. As the animal at first builds the internal layers of the wall, the apertural end lacks this brown layer; in this way the subglobular, light coloured end of the test is formed.

Length of the largest individual 90 mm., diameter up to 3 mm. We must however remember, that most individuals in deep sea gatherings are only fragments. The complete shell must be much longer than 90 mm.

4. *Bathysiphon spec.* Pl. XLIII, fig. 2.

Stat. 211. 5° 40′.7 S., 120° 45′.5 E., depth 1158 m., about 16 specimens.

Test free, cylindrical, tapering very slightly, somewhat irregularly constricted by indistinct

rings due to periodical growth. Wall externally dull, when seen with higher magnification rough. This roughness is caused by irregularly placed sponge spicules, projecting outwards with their pointed ends.

Walls composed mainly of sponge spicules, most of them being very large, intermixed with small sand grains, diatoms, Radiolaria and Foraminifera, such as *Globigerina*. When treated with hydrochloric-acid, the tests of the Foraminifera dissolve, and after some time, the shell becomes very friable; obviously there is but very little organic material present.

The sponge spicules are very irregularly mixed up, and no trace of an internal layer of more regularly arranged spicules — as is the case in *B. filiformis* — has been found up. On the contrary the inner spicules are even projecting into the internal hole of the tube and in this hole they form, together with other large spicules and sand grains, a very conspicuous network of beams, arranged somewhat radially. So the wall of this species internally is not at all smooth, as is the case in all other species of *Bathysiphon*. At first I was inclined to call this new species a *Marsipella*, as the wall shows the rough external surface of this genus. But, this wall being very thick, which is not the case in *Marsipella*, I determined to place it within the genus *Bathysiphon*, though the internal wall is rough and the hole of the tube is filled up with those remarkable beams.

There is very little essential difference between this species and *Bathysiphon filiformis*, which shows the typical tangentially arranged internal layer of spicules, which probably coincides with the abundance of organic material. On the other hand I pointed out, when describing *B. filiformis*, that the genera *Marsipella* and *Bathysiphon* are so closely allied, that it hardly may be necessary to separate them.

There is some probability that the forms, described here, are in reality parts of a kind of *Hyperammina*. I compared them with some good material from the Mexican Gulf and they were nearly identical with the ends of *Hyperammina friabilis* H. B. Brady. But as no proloculum could be found, I dare not solve this question in this direction. So I have described them as a species of *Bathysiphon*, but did not give them a definite name.

III. Genus **Rhizammina.**

Test a simple or branching tube. Wall flexible, chitinous, but fortified with foreign bodies, other Foraminifera or sand grains, attached to the exterior of the tube; apertures formed by the open ends of the tubes.

This description, though very indistinct, must be considered as the only one, suitable for the species, suggested to belong to this genus.

These species occur in deep, or in any case in cool waters and it is very probable that only imperfect specimens have been observed. Nothing is known about the protoplasm of any of the species, belonging to *Rhizammina*.

Only two species are known, viz. *R. indivisa* and *R. algaeformis*. *R. indivisa* is a very doubtful species, as I did not find any trace of protoplasm, when examining some specimens from the Siboga-material, so that I suggest, that we have to do here with some tube of a worm or something like that.

The other species, *R. algaeformis*, must be divided into two species, as I will show in my discussion on this subject.

1. *Rhizammina algaeformis* H. B. Brady. Pl. LI, fig. 3.

Rhizammina algaeformis H. B. Brady, Quart. Journ. Micr. Sci., vol. 19, 1879, p. 39, Pl. 4, figs. 16, 17; Rep. Voy. Challenger, Zool., vol. 9, 1884, p. 274, Pl. 28, figs. 1—11; FLINT, Rep. U. S. Nat. Mus., 1897 (1899), p. 272, Pl. 15, fig. 1; CUSHMAN, Bull. 71, U. S. Nat. Mus., pt. I, 1910, p. 33, textfig. 23; Bull. 104, U. S. Nat. Mus., pt. I, 1918, p. 31, Pl. 11, figs. 2, 3; Bull. 100, U. S. Nat. Mus., vol. 4, 1921, p. 46.

Stat. 221. 6° 24′ S., 124° 39′ E., depth 2798—3112 m., numerous specimens or parts of specimens.

CUSHMAN [1]) gives the following description:

"Test free, consisting of a dichotomously branching flexible tube, forming tangled masses of indefinite size; wall thin, largely chitinous, but with various sorts of foreign matter attached to the exterior, either sand or other foraminiferal tests according to the character of the bottom, surface when free from foreign matter roughened, color of the chitinous tubes brown. Diameter 0.126—0.315 mm.".

This description is quite correct, in the case that no foraminiferal material is attached to the walls, for I believe that the specimens, found with Foraminifera (*Globigerinae*) must be considered as belonging to the following species.

2. *Rhizammina globigerinifera* n. sp. Pl. LI, fig. 2.

Stat. 227. 4° 50′.5 S., 127° 59′ E., depth 2081 m., 3 specimens.

Test composed of a flexible, chitinous tube, from which fine branches are protruding. The tube is agglutinated with *Globigerinae* and other Foraminifera, but the branches are nearly totally naked. The diameter of the tube is 340 μ; length up to 25 mm.; diameter of the branches 75 μ; length of the branches up to 2.5 mm. The ends of the branches are open and they seem to functionate as apertures. One individual shows a short bifurcation of the principal tube, which bifurcation is quite the same as that of the well known form of *Rhizammina algaeformis* with foraminiferal shells attached to its surface. So it is quite possible that this form is identical with the species I have described here. In dried material the little branches are collapsed and have vanished nearly completely. There is some possibility that the *Globigerinae*-bearing form of *R. algaeformis* is some form of *R. globigerinifera*.

1) CUSHMAN, J. A., The Foraminifera of the Atlantic Ocean (Bull. 104, U. S. Nat. Mus., pt. I, 1918, p. 31).

Family REOPHACIDAE.

This family is more heterogenous than one would believe, when studying only superficially the different genera belonging to it. CUSHMAN [1]) groups the following genera in this family:

Hospitella, Aschemonella, Kalamopsis, Nodosinella, Rheophax, Hormosina, Haplostiche, Ammofrondicularia, Turriclavula and *Nodellum*.

If we consider the genus *Reophax*, after which the whole family has been named, we find the remarkable fact, that in typical species, such as *Reophax nodulosus* (now called *Nodosinum gaussicum*) each following chamber is placed on the apertural part of the foregoing, in the same way as is the case with the LAGENIDAE, and as it is fully described in RHUMBLER's work: Die Foraminiferen der Plankton-Expedition, Part I, 1910—11. This mode of forming new chambers, building the basal part of the new chamber on the surface of the apertural part of the last formed one, must be regarded as an expression of high development, while the forming of new chambers with a neck-like passage between them, as is found in *Aschemonella* and even in "*Reophax*" *distans* H. B. Brady, must be considered as primitive: it is the type of growth occurring in *Hyperammina*. BRADY's figure of a section of *Aschemonella* [2]) shows a typical *Reophax*-growth of the chambers, but I could not confirm this observation.

It is very dubious, if a species as *Haplostiche* and as *Nodellum*, must be placed into the family of the REOPHACIDAE, but the Siboga-material containing no specimens of these genera, I must delay this question to the future.

Another fact must be considered here, viz. the description of microspheric specimens in literature. Microspheric forms have been described of several lower Foraminifera, such as *Ammolagena*, *Hormosina* etc. In all cases, figures have been given of these supposed microspheric forms, in which the first chamber was much larger than such a chamber usually is. If we consider the fact, that in higher Foraminifera microspheric specimens begin with an initial chamber, built up by a protoplasm-mass, deriving from the fusion of two flagellospores, we can understand, that the diameter cannot be very large ($\pm$ 12 μ). When studying however the figures given by BRADY, CUSHMAN, etc., one finds first chambers of so-called microspheric forms of 120 μ and more! These forms may be A_1-forms, but they cannot be microspheric ones.

I found some *Reophax scorpiurus*, beginning with a first chamber of about 20 μ inner diameter. In the same sample occurred a specimen of *Reophax lageniformis*, beginning with a

1) CUSHMAN, J. A., The Foraminifera, Sharon 1928, pp. 91—92.
2) BRADY, H. B., Challenger Report, 1884, Pl. XXVII.

much larger first chamber. It seems probable, that this *R. scorpiurus* is nothing else, than the microspheric form of *R. lageniformis*. But only a large material can solve this question and I had not such a material at my disposal in the Siboga-Foraminifera.

I. Genus **Aschemonella**.

Test free, with several tubular or irregularly formed chambers. It is never found in toto, so that the beginning of the test is unknown. Wall thin, arenaceous or consisting of sponge spicules, always with a large quantity of organic, flexible material; apertures mostly more than one, at the end of tubular necks.

Cretaceous to recent. Deep-water forms.

1. *Aschemonella scabra* H. B. Brady. Pl. XLIV, figs. 2—5.

Astrorhiza catenata Norman, Proc. Roy. Soc. vol. XXV, 1876, p. 213.
Aschemonella scabra Brady, Quart. Journ. Micr. Sci., vol. XIX, 1879, p. 44, Pl. III, figs. 6, 7, 12, 13.
Aschemonella catenata Brady, Challenger Report, Zool., vol. 9, 1884, p. 271, Pl. XXVII, figs. 1—11, Pl. XXVII, A., figs. 1—3; CUSHMAN, Bull. 71 U. S. Nat. Mus., Pt. 1, 1910, p. 81; figs. 111—113; U. S. Nat. Mus., Bull. 100, vol. 4, p. 64, Pl. 6, fig. 5.

This peculiar and somewhat doubtful organism has only been met with in dried condition in some tubes with material from station 211: 5° 40′.7 S.; 120° 45′.5 E., depth 1158 m.

Chambers in single or branched series, communicating by tubular necks; in some cases these necks are stoloniferous. Most chambers show two openings at their broadest side; the greater part of the chambers are triangular, but irregular in form and size. Walls very thin, in the Siboga-material mostly composed of one or two layers of sponge spicules, showing the consistence of thin paper. The spiculae are irregularly arranged, except in the neighbourhood of the mouths, where they are radiating from the aperture (see Pl. XLIV, fig. 3).

As other authors (BRADY) found, that the wall was chiefly composed of fine mud with much cement, the Siboga-material shows some peculiarity, as fine mud was to be found in large quantity in the neighbourhood, for other Foraminifera in the same sample, such as *Bathysiphon rufus*, had built their shell especially of fine sand grains. The dried protoplasm showed a very uncommon structure: it consisted mainly of dark little globules.

Aschemonella scabra (= *A. catenata*) has been found only in deeper regions. It is mentioned by BRADY from the Fiji Islands; CUSHMAN found it in the Molucca-sea.

My friend C. VAN RIJSINGE published a very exhaustive study on cretaceous specimens, called by him *Rhabdammina cretacea* [1]). I examined several specimens of this species and came to the conclusion that very probably this *Rhabdammina* is nothing else than an *Aschemonella*. These *Aschemonellae* were however living in a shallow sea, probably associated with a *Hydractinid*. So it would be of some interest to look after living *Aschemonellae* and their association with other living creatures. But too little is known about these very peculiar Foraminifera.

1) C. VAN RIJSINGE, Die Foraminiferen aus dem Senon Limburgens, VIII (Natuurhist. Maandblad, Limb. Genootsch. Vol. 17, N° 7, 1928).

II. Genus **Reophax.**

Test free, elongate, consisting of a row of chambers, beginning with a rounded one. The following chambers with their base built upon the apertural area of the former ones. Walls single, of agglutinated material. Aperture simple, sometimes with a neck.

1. *Reophax dentaliniformis* H. B. Brady.

Reophax dentaliniformis H. B. Brady, Quart. Journ. Micr. Sci., vol. 21, 1881, p. 49; Challenger Report, Zool., vol. 9, 1884, p. 293, Pl. 30, figs. 21, 22; CUSHMAN, Bull. 71, U. S. Nat. Mus., Pt. 1, 1910, p. 87, fig. 121; CUSHMAN, Bull. 100, U.S. Nat. Mus., vol. 4, 1921, p. 68, Pl. 12, fig. 4.

As CUSHMAN pointed out in his last mentioned work, specimens from the Philippine seas "are not quite typical, having as a rule the chambers shorter and more rotund, than in the type". This fact in mind I classified the specimen, figured on Pl. XLVII, fig. 3, in this species. It shows the fine agglutination, characteristic for this species, but not its typical features. It was found in material from station 77: 3° 27′ S., 117° 36′ E.; depth 59 m., Borneo-Bank.

2. *Reophax scorpiurus* Montfort.

Reophax scorpiurus Montfort, Conch. syst. vol. 1, 1808, p. 330, 83me genre; H. B. Brady, Chall. Report, Zool., vol. 9, 1884, p. 291, Pl. 30, figs. 12—17; CUSHMAN, Bull. 71, U. S. Nat. Mus., Pt. 1, 1910, p. 83, figs. 114—116; CUSHMAN, Bull. 100, U. S. Nat. Mus., Vol. 4, 1921, p. 65, Pl. 6, fig. 6; FLINT, Rep. U. S. Nat. Mus., 1897 (1899), p. 273, Pl. 16, fig. 3, Pl. 17, fig. 1.

Some very typical specimens were found at Siboga-station 77: 3° 27′ S., 117° 36′ E.; depth 59 m., Borneo-Bank. One of them is figured in Pl. XLVII, fig. 4.

3. *Reophax spiculifera* H. B. Brady. Pl. XLIX, fig. 9.

Reophax spiculifera Brady, Quart. Journ. Micr. Sci., vol. XIX, N. S., 1879, p. 54, Pl. IV, figs. 10, 11; Challenger Report, Zoology, Vol. 9, 1884, p. 295, Pl. XXXI, figs. 16, 17; CUSHMAN, Bull. 71, U. S. Nat. Mus., Pt. I, 1910, p. 92, figs. 132—133.

A single specimen was found in a sample from station 211: 5° 40′.7 S.; 120° 45′.5 E; depth 1158 m.. It does not differ much from BRADY's fig. 16, mentioned above. It seems to be a rare, tropical form, from deeper regions. It was found by BRADY near the Fiji Islands and near Tahiti, at about 600 fathoms depth. CUSHMAN did not meet with it in the material he examined from the North Pacific. Very little is known about it, and in the "Summary of Results" of the Challenger Report, according to CUSHMAN, "it is recorded with a question mark from stations 237 and 246, 1875 and 2050 fathoms".

4. *Reophax pilulifer* H. B. Brady.

Reophax pilulifer H. B. Brady, Challenger Report, Zoology, vol. 9, 1884, p. 292, Pl. XXX, figs. 18—20; CUSHMAN, Bull. 71, U. S. Nat. Mus., Pt. 1, 1910, p. 85, figs. 117, 118; Bull. 100, U. S. Nat. Mus., vol. 4, 1921, p. 66, Pl. 12, fig. 1.

The species has been found in several specimens, though rare and not at any of the

Siboga-stations. I discovered it in some material, given to Prof. M. WEBER by Mr. VAN NOUHUYS, gathered 20, IV, 1914, at Kwandang bay, North Coast of Celebes, 500—700 fathoms deep.

The specimens were of a deep dark colour, nearly black, but showed all the characteristics of *R. pilulifer*, as given by CUSHMAN (1910). One specimen, figured in my Plate XLVII, fig. 2, proved to be megalospheric, and was nearly identical with that, figured by CUSHMAN (1910) in his fig. 117. My other figure (Pl. XLVII, fig. 1) is that of a finer shaped specimen, that begins with a much smaller proloculum. It is possible, that it is microspheric. But it is somewhat large (± 200 μ) and as the bionomics of these lower groups of Foraminifera are very unknown I dare not decide whether it is microspheric or not. It is probable that it is a megalospheric form with small proloculum, that of the other specimen measuring 420 μ.

III. Genus **Nodosinum.**

Only distinguishable from *Reophax* by its mouth, which is radiate, at least in A_2-forms.

I am not quite sure, that this difference is enough to establish on it a new genus, as RHUMBLER did.

1. *Nodosinum gaussicum* Rhumbler. (Pl. XLVIII; Pl. XLIII, fig. 8; Pl. XL, figs. 2, 5—8).

Arnodosinum py-gaussicum Rhumbler, Foraminiferen der Plankton-Expedition, Pt. II, 1913, p. 452; Pt. I, 1910/11, Pl. XX, figs. 1, 2.
Reophax nodulosa H. B. Brady (part.), Quart. Journ. Micr. Sci., N. S., vol. 19, 1879, p. 52, pl. IV, figs. 7, 8; Challenger Report, Zoology, vol. 9, 1884, p. 294.

This very peculiar species occurred in the Siboga-material from two stations only, viz. station 221: 6° 24′ S., 124° 39′ E., depth 2798 m. (rarely) and station 223: 5° 44′.7 S., 126° 27′.3 E., depth 4391 m. (abundant).

The only (short) description of this species and also of the genus, has been given by RHUMBLER in his Report of the "Plankton-Expedition", cited above. No other records are given in literature, but I am convinced, that it must have been found also in other deeper stations. The specimens are very difficult to distinguish from the typical *Reophax nodulosa*, so I think in more than one case they have been overlooked.

Two forms could be distinguished, one (only very few specimens) with a small proloculum (± 100 μ), the other (much commoner) with a much larger proloculum (up to 1000 μ). I cannot believe that the first mentioned form was microspheric, the proloculum being too large to derive from a zygote. So I think we have to do with the two megalospheric forms.

The form with little proloculum is identical with a typical *Reophax nodulosa*, figured by BRADY (Chall. Rep. Pl. XXXI, figs. 3 and 4).

The form with the larger proloculum shows the features of BRADY's figures 1 and 5, called by CUSHMAN (Philippines, 1921, p. 69) var. *hormosinoides*.

A single specimen in the material of station 223 showed the typical characteristics of that, figured by BRADY (Chall. Rep.) on Pl. XXXI, fig. 2. I believe, that this specimen can only be a different megalospheric form, though I do not yet know, what form it may be. Most of the specimens showed the characteristics of the species, as given by RHUMBLER. The test is large

and coarsely arenaceous, chambers more long than broad, pyriform, especially the later ones. The aperture has always, even in the first chamber, a very typical asteroid shape, due to four or five longitudinal ribs, situated at the inner wall of the apertural part of the chamber. These ribs have been described by RHUMBLER as "Zotheken": "Derartige Zotheken, also Nischenbildungen innerhalb der Wand von relativ groszer Regelmäszigkeit, habe ich bei einem "äuszerlich" der *Reophax nodulosa* Brady's durchaus gleichen *Arnodosinum py-gaussicum* nov. m.!! der Gauss-expedition angetroffen, dessen genauere Beschreibung ich auf meine spätere Bearbeitung des betreffenden Materials verschieben musz. Der Schalenhohlraum zeigt hier, besonders deutlich in den späteren, mehrere grosze Nischen, die durch regelmäszige, nicht sehr hohe längsgerichtete Scheidewände voneinander getrennt sind (Textfig. CLXIII); die Scheidewände selbst laufen bis nach der Mündung hin und geben dieser eine rosettenförmige Gestalt". This description is so very characteristic, that, though RHUMBLER never described the species more accurately, as he never found the time to work at the Gauss-material, I could easily recognise this form. As the modern nomenclature proposed by RHUMBLER did not find application, I mean to give the name *Nodosinum gaussicum* to the species. The new genus *Nodosinum* is only based upon the very peculiar "Zotheken", but as RHUMBLER already created it as *Arnodosinum*, I found no freedom to drop it.

The test is composed of sand grains and other foreign material, with fine organic matter, which in a newly built wall shows no colour but later on becomes yellowish and brownish. Only some specimens with a very large proloculum do not become brownish, but get a grey colour.

As I mentioned already above, there exists also a third form, with a small proloculum, and of a much smaller size. The chambers are also pyriform, but the greatest breadth of the later chambers is at the posterior end of each chamber. These forms lack any trace of ribs, so characteristic for the genus *Nodosinum*. So I was first inclined to give them the name *Reophax nodulosa*. But as they occurred between the typical *Nodosinum* in both gatherings and moreover the finer structure was absolutely identical with that of *Nodosinum*, I think I am right, when considering them as microspheric or A_1-forms of *Nodosinum gaussicum*. As always in the Foraminifera B- or A_1-forms show more primitive characteristics, it is not so very strange, that no ribs have been found in the chambers. If new investigations should corroborate this opinion, it would be more justifiable to drop the genus *Nodosinum* and to call the species *Reophax gaussicum*, as only the megalospheric form shows the peculiar features of "Zotheken" and the microspheric (or A_1-form) shows real *Reophax* characteristics.

Family ANOMALINIDAE.

Studying the different species of *Carpenteria* of the Siboga-material, I came to the conclusion, that the early stages of specimens of this genus are always identical with typical ANOMALINIDAE, as they are attached with the dorsal surface, which is always flattened. These stages are also found in another genus, *Placopsilina*, in which the coarse pores are present too, which are so characteristic for the genus *Carpenteria*. These coarse pores, are also found in the genera *Cibicides* and *Cibicidella*, belonging both to the ANOMALINIDAE.

So I propose to bring the genera *Placopsilina* and *Carpenteria*, with *Anomalina*, *Cibicides* *Webbina*, etc. together to the family of the ANOMALINIDAE.

On the other hand I think it wrong to consider the genus *Rupertia* as allied to *Carpenteria*, as CUSHMAN [1]), and other authors suggest. I have examined beautiful specimens of *Rupertia stabilis* (the material however belongs to another expedition) and they show sufficiently different characteristics to separate them from *Carpenteria* and its allies.

I have made some allusions to the fact, that the genus *Sporadotrema* must be closely allied to *Carpenteria*. It is probable, that *Polytrema* and *Homotrema* and other PLANORBULINIDAE, are allied to *Sporadotrema*. So I believe, that CUSHMAN (l. c. 1928) was right to place the ANOMALINIDAE near the PLANORBULINIDAE.

Description of the family:

Test free, or attached with the dorsal side, which is typically flattened or concave. Chambers arranged in a trochoid manner, at least in the earlier stages; in some species the later ones becoming very large and irregularly formed, and then often arranged in a high pillar, or in a long row, creeping along the surface of the object to which the individual is attached. Wall calcareous, coarsely perforate, often possessing irregular knobs of chalk. Aperture in some species simple, in others more complicated, cribriform, or at the ends of tubular necks of the chambers.

I have removed the genus *Placopsilina* from the family, called by CUSHMAN [2]) PLACOPSILINIDAE, and placed it in the neighbourhood of *Carpenteria*, as *Placopsilina* (and probably also *Haddonia*)

1) CUSHMAN, J. A., The Foraminifera (Sharon, 1928, p. 331).
2) CUSHMAN, J. A., l. c. 1928, p. 176.

shows no traces of agglutination, but a calcareous wall, with coarse pores (the calcareous knobs on its surface being built like an agglutination of coralsand).

I have shown [1]), that the cretaceous genus *Polyphragma*, on the other hand shows true agglutination and no marks of pores, so that this genus is allied to *Trochammina*. It must be regarded as a type-genus of a new family, that of the POLYPHRAGMIDAE, as the family of the PLACOPSILINIDAE does not exist any longer, its type-genus having been removed from it.

I. Genus **Placopsilina.**

Attached individuals, in forma A_2 forming a very primitive coil, in forma A_1 and B however, typical anomaline. Later chambers uncoiled. Pores coarse, wall calcareous with irregular protuberances. Length of the shells up to 5 mm.

1. *Placopsilina cenomana* d'Orbigny. Pl. XL, fig. 9, Pl. XLIX, figs. 1—8, figs. 10, 11.

Placopsilina cenomana d'Orbigny, Prodr. Pal., vol. 2, 1850, p. 185, n° 758; CUSHMAN, U. S. Nat. Museum, Bull. 100, 1921, p. 95.
Haddonia torresiensis Chapman, Journ. Linn. Soc. London, Zoology, vol. 26, 1898, p. 453.
? *Bdelloidina aggregata* Carter, Ann. Mag. Nat. Hist., ser. 4, vol. 19, 1877, p. 201.

This form occurred at only two stations of the Siboga expedition, viz.:

Stat. 226. 5° 26'.7 S., 127° 36'.5 E., depth 1595 m., one single individual on a shell, and
Stat. 289. 9° 0'.3 S., 126° 24'.5 E., depth 112 m., on coral.

Beautiful specimens on various shells were found in the collections of the parish Lyceum at the Hague (Holland), gathered on the coasts of Ambon.

Most of the individuals correspond with the descriptions, given by different authors of *Placopsilina cenomana.*

The first chambers of these specimens are relatively large, forming a single, irregular coil. The later portion is not coiled, and is continued in a linear series. The aperture is somewhat difficult to observe.

Other specimens show a close-coiled spiral, beginning with a small proloculum. The later chambers form an irregular series of chambers, which cannot be distinguished from those, described by CHAPMAN as *Haddonia torresiensis.* The aperture shows in some cases the typical tooth, or sometimes it is a narrow slit.

The structure of the chambers is always simple; no labyrinthic outgrowths of the chamber-walls could be found. Only in the neighbourhood of the apertures the chamberwalls show thickened lips, which made some authors suggest that the structure of the shell was labyrinthic. I have discussed this matter already in my description of *Polyphragma cribrosum* of the maestrichtian chalk [1]); as the "lips" of *Haddonia* are much smaller, it is confusing to call those chambers labyrinthic. CHAPMAN says in his original description (p. 454): "The interior of the test is smooth or even polished and partially subdivided by imperfect and curved septa (irregularly

1) HOFKER, J., Die Foraminiferen aus dem Senon Limburgens IX (Natuurhist. Maandbl. vol. 17, 1928, N° 7, pp. 105—108).

labyrinthic)". The chamberwall shows in both forms a very typical structure. The entire wall is composed of chalk-material, which forms irregular pits and outgrowths of the surface, giving the illusion of sand grains. But exactly as is the case in *Polyphragma*, they can be dissolved totally in acid and I am convinced that these "sand grains" are formed by the animal itself. When studying the wall inside, one observes a large number of very regularly placed pores, which are relatively wide. Canadabalsam-preparations showed, that these pores are very like those, found in *Carpenteria* or *Sporadotrema*, as CHAPMAN has already mentioned. It is very remarkable that even the typical *Placopsilina*-form shows these peculiar pores; the chalk-material of the wall is very irregular of constitution and this is the reason why these pores are very difficult to observe in slides. This statement is of some systematical importance as RHUMBLER (Die Foraminiferen der Plankton-Expedition, pt. II, 1913, p. 446) says: "Das Genus ist unsicher, weil keine Angaben über die Art einer eventuell anzutreffenden Perforation vorliegen".

It is possible, that the genus *Bdelloidina* belongs also to the same species, forming only a variety due to trimorphism. I had, however, no material at my disposal to state this suggestion.

As in CARTER's description of the genus *Bdelloidina* (Ann. Mag. Nat. Hist., ser. 4, vol. 19, 1877, p. 201) a typical perforation has been shown and the wall consisted of calcareous material, I am sure that this *Bdelloidina* shows in its test the characteristics of *Placopsilina*. Why this "species" obtained a special generic name I do not know.

In CUSHMAN's new work on the systematics of the Foraminifera [1]) he has created a family of the PLACOPSILINIDAE, in which are placed the genera *Placopsilina*, *Bdelloidina*, *Haddonia*, *Stacheia*, *Polyphragma* and *Stylolina*.

As I pointed out already, *Polyphragma* shows no typical labyrinthic structure, nor is this the case in *Haddonia*, as CUSHMAN suggests. *Placopsilina* shows pores, and the wall is only apparently arenaceous.

Haddonia and *Placopsilina* have quite the same structure of the wall and occur together at both stations, so I am sure that they form one single species.

As the *Haddonia*-form begins with the smaller proloculum, it shows more primitive characteristics; the most striking difference between "*Haddonia*" and *Placopsilina* is the high development of the initial spiral. This spiral shows a very close resemblance with typical Cibicidinae (= Truncatulinae), especially *Cibicidella variabilis* d'Orbigny with its distinct lip at the aperture and its coarse pores.

So I am convinced that *Placopsilina* must be placed in the group of the Cibicidinae, which are also related to *Carpenteria*.

The most typical characteristic of the Cibicidinae is, that the test is attached with its dorsal side (CUSHMAN, l. c. p. 322); this is also the case in the first spiral of *Haddonia*.

II. Genus **Carpenteria.**

This genus, created by GRAY in 1858, has given much difficulties to earlier authors as to its systematical place. The different species have mostly been based upon very poor material, so that the bionomics or the internal structure could not be considered.

1) CUSHMAN, J. A., Foraminifera (Sharon, 1928, p. 176).

Though the Siboga-material contains no rich quantities of specimens, yet it has been possible to throw some more light on the different species of this peculiar genus. Nearly all species, known hitherto, have been met with in the Siboga-collections, so we can give a more exhaustive account of the entire genus.

All species are attached forms, beginning with a typical spiral of chambers. In megalospheric forms this spiral begins with a large proloculum, followed by a relatively small number of chambers, showing the aperture placed at the umbilical margin of the last chamber and having very coarse pores. This aperture developes a round neck. The ventral side only shows the inflated chambers of the last whorl, so that an umbilicus, more or less deep, remains. The dorsal side is attached to the substrate. The later chambers show the tendency to grow out into fingershaped marginal protuberances. These outgrowths are rounded in *Carpenteria monticularis* and very well developed into stolons in "*C. herdmani*", or in branched points in *C. rhaphidodendron*. Secondly they often try to grow out into a spiral curled round an axis vertical to the plan of the first spiral. In these cases they look like little corals; *C. proteiformis* shows the most simple structure of this group, the highest developed form has been called *Sporadotrema* and has been mentioned already in part I of this Monograph. Some forms of the latter possessing in the earlier stages typical carpenterian characteristics, I think *Sporadotrema* to be a real *Carpenteria*. It is not very probable that the genus *Rupertia* belongs also to the *Carpenteria*-group, but the first development has not yet been studied exactly.

The genus *Carpenteria* has been placed by BRADY (Challenger Report, Part 9, Zoology, p. 676) in the neighbourhood of *Anomalina*, and has been compared by this author with *Truncatulina*, recently named by CUSHMAN *Cibicides* and *Cibicidella*. This systematical place must be the right one, as microspheric specimens cannot be distinguished from *Cibicidella variabilis* (d'Orbigny).

As no traces of a canalsystem are visible, there is not any relation with the ROTALIIDAE. On the other hand the relation with some forms of the PLANORBULINIDAE is very obvious, especially when we think of *Sporadotrema*, *Homotrema* and *Polytrema*. *Sporadotrema* particularly is nothing else than a true *Carpenteria* and I believe that the generic name *Sporadotrema* Hickson must be put aside. There are no reasons to create a family of the RUPERTIIDAE, as CUSHMAN did in his work on the Foraminifera (1928), for *Carpenteria* shows all the typical features of real Cibicidinae. So I am inclined to place the genus in the family of the ANOMALINIDAE. As the Siboga-expedition did not gather specimens of *Rupertia stabilis*, no conclusions are made here about the systematics of this genus *Rupertia*.

1. *Carpenteria utricularis* (Carter). Pl. L; Pl. LII, figs. 1—5, 8, 9.

Polytrema utriculare Carter, Ann. Mag. Nat. Hist., ser. 4, vol. 17, 1876, p. 211, pl. 13, figs. 11—17.
Carpenteria utricularis Carter, Ann. Mag. Nat. Hist., ser. 4, vol. 20, 1877, p. 176; H. B. BRADY, Rep. Voy. Challenger, Zoology, vol. 9, 1884, p. 678, Pl. 99, figs. 6, 7, Pl. 100, figs. 1—4; CUSHMAN, U. S. Nat. Mus., Bull. 100, vol. 4, 1921, p. 360, Pl. 73, figs. 4, 5.
Carpenteria monticularis Carter, Ann. Mag. Nat. Hist., ser. 4, vol. 19, 1877, p. 211, Pl. 13, figs. 9—12; H. B. BRADY, Rep. Voy. Challenger, Zool., vol. 9, 1884, Pl. 99, figs. 1—5; CUSHMAN, U. S. Nat. Mus., Bull. 71, pt. 5, 1915, p. 48, Pl. 20, fig. 3; Bull. 100, vol. 4, 1921, p. 362.

Ramulina herdmani Dakin, Ceylon Pearl Oyster Fisheries, Suppl. Rep., pt. 5, 1906, p. 236, Pl. 1, figs. 1—6, textfigs. p. 227.
Anomalina polymorpha Costa, Atti Accad. Pont., vol. 7, 1856, p. 252, Pl. 21, figs. 7, 9; CUSHMAN, U. S. Nat. Mus., Bull. 100, vol. 4, 1921, pp. 324—325, Pl. 61, 62.

The different forms of this species occurred at the following Siboga-Stations:

Stat. 51. Madura bay, southern part of Molo-strait; depth from 69—91 m; all forms.
Stat. 89. Pulu Kaniungan Ketjil; depth 11; *C. utricularis* and *C. monticularis*.
Stat. 105. 6° 8′ N., 121° 19′ E., depth 275 m.; *C. monticularis*.
Stat. 204. 4° 20′ S., 122° 58′ E., depth from 75—94 m.; all forms, except *Anomalina*.
Stat. 253. 5° 48′.2 S., 132° 13′ E., depth 304 m.; *L. monticularis*, *Anomalina polymorpha*.
Stat. 260. 5° 36′.5 S., 132° 55′.2 E., depth 90 m.; all forms.

C. utricularis and *C. monticularis* have also been discovered on stones found at Sebesi in the bay of Batavia by Dr. H. BOSCHMA (1921).

It is very difficult to describe such a variable species as *Carpenteria utricularis*. So firstly I will give here my opinion about the relations between all forms, mentioned as synonyms of the species. *Carpenteria utricularis* is the first described species of the *Carpenteria*-group and *Anomalina polymorpha*, though described much earlier, shows too little typical characteristics to drop the name *Carpenteria* and to call all forms *Anomalina*. So I gave the entire species the name *Carpenteria utricularis*.

Three forms are megalospheric, viz. *C. utricularis*, *C. monticularis* and *R. herdmani*; *Anomalina polymorpha* (especially the varieties distinguished by CUSHMAN as var. *cervicornis* and var. *siphonifera*) was in all specimens I observed microspheric. As all intermediate stages between *C. utricularis* and *R. herdmani* can be found up and *R. herdmani* only differs by a higher development of growth and another structure of the wall, while the initial chamber of *R. herdmani* (± 400 μ) is larger than that of *C. utricularis*, I believe that these two forms show one half of the megalospheric series of this species. The other half, the megalospheric specimens with small proloculum, is formed by *C. monticularis*.

I will now try to describe the different forms mentioned above and begin with the megalospheric ones.

1. Form, called in literature *C. utricularis*.

In the Siboga-collections the chambers of this form are more firmly built than those of *C. monticularis*, so that the animal looks more compact. Often the irregular form of the substrate causes a more wild growth of the shell. The foramina of the last whorl of chambers can generally all be distinguished at the ventral, visible, side. The mouth of the last chamber shows radiating protuberances. Chambers in most cases inflated. They overlap each other like the tubes of vermicides, so that the entire aspect of the shell is very irregular. Some individuals are like a turban with a plume. The network-structure of the walls is very characteristic. Pores are only seen in the mashes between the network of the little walls.

The initial chamber has a diameter of about 350 μ and the first chambers form a short spiral. The following three are more or less oval or reniform.

After these first four chambers follows a series with lobated margin, looking very much like the basal chambers occurring in *Sporadotrema*; this is such a remarkable characteristic, that I do not hesitate to place *Sporadotrema* in this group of the ANOMALINIDAE (CIBICIDAE),

though other characteristics of *Sporadotrema* show some relation with the PLANORBULINIDAE. On the other hand some "varieties" of *Anomalina polymorpha* also possess the typical lobated chambers, I mentioned here. This is the reason why I am inclined to group these microspheric specimens within this *Carpenteria*-species.

The pores are a little larger and wider than those of *C. monticularis* and more irregularly placed. They look very much like those of *R. herdmani*.

A somewhat peculiar form was found by Dr. H. BOSCHMA at Sebesi on a piece of coral and at station 81 (Pulu Sebangkatan, Borneo-bank) on a sponge, showing the habitus of an old volcano, as the chambers did not grow larger to the periphery. Between the chambers deep furrows are found; the first chamber belongs to the smallest megalospheric ones and the chambers of the initial spiral look very much like those, found in *Anomalina polymorpha* var. *cervicornis*, with lobated margin. In normal specimens the number of the chambers of the last whorl is 7 or 8, in this form of *C. utricularis* it is 12. It looked like *C. monticularis*, only the structure of the walls was that of *C. utricularis*. The first chamber was relatively small, 160 μ.

2. Form, named in literature *Ramulina herdmani* Dakin. It was first described by DAKIN in 1906. Large colonies occurred in the Siboga-material from station 204; beautiful specimens were found at station 51. As DAKIN found colonies composed of large quantities of individuals heaped together, it was very difficult to discover the real structure of separate specimens. I cannot, like DAKIN, come to the conclusion, that this species belongs to *Ramulina*. It is known, that this "genus" belongs to the LAGENIDAE. DAKIN says in his publication: "The genus *Ramulina* of RUPERT JONES, 1875, is defined by BRADY in the Challenger Report as follows: "Test free, branching; consisting of a calcareous tube, swollen at intervals so as to form more or less definite, often irregular segments, from which lateral stolons or branches are given off. Texture hyaline". When examining the "species", mentioned here, there is no confusion possible with real *Ramulina*; only the "lateral stolons" obviously have been considered as a criterium by DAKIN; but every one, aequainted with material of "*Ramulina*", knows that these stolons are very different from those of the form, studied by DAKIN. But DAKIN saw the difference between the description given by BRADY and the species he found in the Investigator-collections, saying: "Some alteration will, however, have to be made in this definition of the genus, since this species is certainly not hyaline. The species described by BRADY is *R. globulifera*, and from the description it appears that the swelling referred to in the definition of the genus arise only at intervals and are connected by tubular portions. In our Ceylon species on the other hand, there may be a whole series of globular segments opening directly one into the other". I can add a large series of other differences between true *Ramulina* and this species: the so-called *R. herdmani* is an attached form, with a very thick shell with large pores, and the different chambers are arranged in a spiral round a vertical axis. Most chambers form only one single stolon, reaching the surface of the coral or stone, on which the shell is attached; DAKIN calls these tubes "pipes", the globular chambers are called "ampullae". But these ampullae are real chambers, connected with each other by large foramina and giving off those typical "pipes". The exterior of the shell is smooth, here and there round knobs of clear shell-material are formed; real *Ramulina* however is very thin-walled and its walls show in most forms fine

thorny protuberances. DAKIN's description of the mouths of the shell is quite right: "the walls of the ampullae are prolonged to form 4 or 6 protuberances of unequal size which surround the orifice".

CUSHMAN was the first to suggest that this *Ramulina herdmani* really was a *Carpenteria*, but he identified it with MÖBIUS' *Carpenteria raphidodendron*, which cannot be true. Only the irregular masses of colonies, DAKIN figured in his textfigures, show identical points with figure 9 of Pl. V in the beautiful monograph of MÖBIUS.

So my first investigations about this peculiar form were, to search for the initial set of chambers. It is very difficult to find these chambers in the irregular heaps of individuals, like those of DAKIN's and mine from station 204 of the Siboga-expedition. But they can easily be found, when examining singular specimens, attached to corals. The first chamber is a very large one (± 400 μ) and is followed by a spiral of three other chambers. These four chambers possess foramina at the ventral side, near the umbilicus; the dorsal, flattened side is attached to the substrate. So we have to do with a typical anomaline species. The other chambers form a column and their "pipes" give it a kind of support. I also found young specimens; they cannot be distinguished from the forms of *Carpenteria utricularis* figured by BRADY (Pl. XCIX, figs. 6 and 7). The "pipes" mentioned by DAKIN are nothing else than the outgrown parts of the chambers (also met with in *C. utricularis*), which form here the ridges of the slopes of the volcano-like shell. As, however, the chambers are very soon situated 3 and more mm. above the level of the substrate, these outgrowths become free stolons. All these facts affirm the opinion, that *Ramulina herdmani* is nothing else than the form with the largest proloculum of the megalospheric series of *Carpenteria utricularis*.

3. Form, known as *Carpenteria monticularis*. The initial chamber has a diameter of about 180 μ. It is followed by three reniform chambers and this spiral terminates in a large round chamber, which can also be found in *Ramulina herdmani*. The smooth surface only shows the opening of pores; these pores begin as narrow tubes but their mouths are somewhat enlarged. When the walls of two chambers meet, their pores communicate. So the walls are double, like in other *Carpenteriae*. Canadabalsam-preparations do not show any trace of a canalsystem.

4. Form, known as *Anomalina polymorpha*. I believe this species is nothing else than the microspheric form of the other three, mentioned above, because:

a. Only in samples, in which *Carpenteria utricularis* was found, *Anomalina polymorpha* was also gathered.

b. All specimens were microspheric, the first chamber measuring about 20 μ.

c. The pores of the thin-walled specimens of *A. polymorpha* show the typical arrangement and large opening like in *Carpenteria*.

d. The specimens, when alive, are obviously found attached to corals etc. with their dorsal side.

e. The foramen often shows the irregular outgrowths typical for *Carpenteria*.

f. The later chambers of *Anomalina polymorpha* often show a tendency to form stolons, like CUSHMAN's figures show (1921, Pl. 62, figs. 1*a*, *b*; figs. 2*a*, *b*).

So we can give the following enumeration of the different forms of *Carpenteria utricularis*:

Forma A_1: (= *Carpenteria monticularis*); wall smooth, with large pores.

Forma A_2: (= *Carpenteria utricularis* and *Ramulina herdmani*); wall with network of ridges or with protruding chalkmasses; in highly developed specimens the chambers grow out to a pillar of large size, with rhizomorphous stolons.

Forma B: (= *Anomalina polymorpha*); anomalid shells with coarse pores, later chambers growing more irregularly, but never growing so wildly as to form the carpenterian type.

2. *Carpenteria proteiformis* Goes.

Carpenteria balaniformis, var. *proteiformis* Goes, Kongl. Svensk. Vet. Akad. Handl., vol. 19, 1882, p. 94, Pl. 6, figs. 208—214; Pl. 7, figs. 215—219.
Carpenteria proteiformis H. B. Brady, Rep. Voy. Challenger, Zoology, vol. 9, 1884, p. 679, Pl. 97, figs. 8—14; CUSHMAN, Bull. 71, U. S. Nat. Mus., pt. 5, 1915, p. 49, Pl. 20, fig. 2, Pl. 21, fig. 1; Bull. 100, vol. 4, 1921, p. 361, Pl. 73, figs. 2, 3.

Stat. 260. 5° 36'.5 S., 132° 55'.2 E., depth 90 m.; 9 specimens.
Stat. 303. Haingsisi, Samau-island; up to 36 m.; 8 specimens.

Description.

Shell begins with a short attached spiral, than a column of spirally arranged chambers follows. Pores very coarse, fusing together before reaching the surface. Aperture at the end of the column, forming a short neck with irregular margin.

I do not know whether this form is a species or only a form of *C. utricularis*. It has been called *Rupertia* by BRADY, but in his Challenger Report he called it, after GOES, *Carpenteria*. As I had no real *Rupertia*-material at my disposal, I could not decide whether we had to do with a real *Rupertia* or a *Carpenteria*. The embryonic apparatus consists of a typical anomaline spiral, and all chambers are coarsely perforate. I have found only megalospheric specimens, the first chamber being somewhat oval, followed by three larger ones, and a very large chamber, overgrowing this initial spiral. The mouths of the last chamber of the columnar spiral, which forms the larger part of the test, are generally ornated with irregular necks. The surface mostly shows a fine areolation, but not so prominent as is the case in *Carpenteria utricularis*. The pores are very typical, showing all characteristics of those, described in *Sporadotrema cylindricum*: towards the periphery of the wall they coalesce and end into the mashes of the areoline network; these areolae are analogous to those of *Sporadotrema*. This also is the case in *Carpenteria utricularis*, only here the pores themselves are narrower. The chambers are situated round a central axis, and their foramina are situated in the axis of the column, exactly as is the case in *Sporadotrema*; they show a thickened neck of pseudochitin. So I could make two different suggestions, when studying this *Carpenteria*:

1. *Carpenteria proteiformis* is a white species of the genus *Sporadotrema*;
2. *Sporadotrema* is nothing else than a typical *Carpenteria*.

Both suggestions lead to the conclusion that *Sporadotrema* is very closely allied to the genus *Carpenteria*; even the peculiar form of *Carpenteria utricularis*, viz. the so-called *Ramulina herdmani* shows very typical *Sporadotrema*-characteristics, f. i. its stolons have also been met with in *Sporadotrema* (see Part I of this Monograph, Pl. IX, fig. 3).

I have classified *Sporadotrema* among the PLANORBULINIDAE especially because both genera *Sporadotrema* and *Planorbulina* show in the later chambers more than one foramen. But examining *Carpenteria proteiformis* I also found those multiple foramina. As no other planorbuline characteristics of some importance have been found in *Sporadotrema*, I am now inclined to believe I am right when classifying *Sporadotrema* in the group of the ANOMALINIDAE.

3. *Carpenteria rhaphidodendron* Möbius.

Carpenteria raphidodendron Möbius, Beitr. Meeresfauna der Insel Mauritius etc., 1880, p. 81, Pl. 5, figs. 6—10; Pl. 6, figs. 1—6.

Stat. 89. Pulu Kaniungan Ketjil; shore.
Stat. 225. 5700 m. M. N. 279° E. from southpoint of south Lucipara-island; depth 694 m.
Stat. 240. Banda; reef.

Description.

Large colonies of a typical, white colour form irregular masses of about 30 mm. height. Each chamber shows the form of a hand, with finger-like stolons, ending open. At the base of each colony initial sets are present, forming a short spiral of chambers. The stam of the colony is equally formed by spirally arranged chambers. Pores coarse, opening into cavities of the surface. Only megalospheric specimens are hitherto known.

A very great confusion about this species in literature makes it extremely difficult to give an account of the authors who mentioned it. It is possible that CHAPMAN was right when describing it from Funafuti; it is also mentioned by CUSHMAN (1921)[1]) from Sulu Archipelago, off Tawi Tawi and north of Balabac Strait. But CUSHMAN has identified it with *Ramulina herdmani* Dakin. As CUSHMAN gives no figures himself, one cannot know whether he found MÖBIUS' *Carpenteria* or DAKIN's "*Ramulina*".

The form found by the Siboga-expedition was megalospheric. Large colonies, which show in outer form very great resemblance with *Polytrema*, are situated on corals and stones, at the stations mentioned above. On a large base of irregular shape grow branches, ending sharply and often very irregularly. All branches consist of a spiral of chambers, possessing outgrowths like the pointed fingers of a hand; such forms are also found in "*Ramulina herdmani*" where those fingers give rise to the stolons; in *Carpenteria rhaphidodendron* sometimes they form the pointed ends of the branches, sometimes they creep along the columns of chambers, filling up the ridges between the chambers. Heaps of sponge spicules are found in the protoplasm, exactly as in other *Carpenteriae*.

1) CUSHMAN, J. A., Bull. 100, U. S. Nat. Mus., 1921, p. 363.

When studying the base of a colony, I found that it contained a large number, ± 15, of embryonic apparates, so that each "individual" in reality is a plurivalent one. It is very interesting that *Sporadotrema cylindricum* also shows this phenomenon. All initial chambers are megalospheric, measuring 125—166 μ and are somewhat oval shaped. They are surrounded by three chambers, whose diameters increase gradually; the fifth is a very large one with finger-shaped outgrowths. These outgrowths are also found in some forms of *Carpenteria utricularis* and so MÖBIUS was right when classifying this new species among the *Carpenteriae*.

The colonies have a greyish-white colour; the pores of the chambers are irregularly placed and not so coarse as is the case in some other *Carpenteriae*. The shell is thin, especially in the outer branches; here and there sponge spicules are found in the chalk of the chamberwalls.

Family PENEROPLIDAE.

This family possesses very peculiar characteristics and all the genera belonging to it show these characteristics without exception, which makes it easy to determine the peneropline nature of a shell. Genera, which do not show the typical peneropline features in all forms, must be considered as belonging to other families and are to be removed from the PENEROPLIDAE.

On the other hand we can state, that earlier authors have not studied trimorphism; this lack of our knowledge has caused the creation of many genera and species, which must be abolished, now that we know much more about the different generations of the species, as I will show, when dealing with the special forms.

CUSHMAN in his handbook on the Foraminifera[1]) distinguished 13 genera, which he joined in the following description of the family:

"Test imperforate except the proloculum and second chamber which are distinctly perforate, calcareous, in general planispiral in the young, then becoming annular or uncoiling; chambers typically divided into chamberlets in all but the most primitive genera; aperture in the simpler forms slit-like, becoming multiple in the complex forms or rounded and terminal in the uncoiled forms". This sharp and clear definition needs some alteration, as our studies on the genera of the family of the PENEROPLIDAE have discovered some further data of the anatomy as well as the systematical place of several genera and species.

So we have to consider first that the proloculum and the second chamber of the megalospheric A_1-form only, are typically perforated with very fine pores, that the prolocula and the following chambers of all other forms are characterised by furrows in the wall, which give rise to very thin-walled spots.

The walls are typically calcareous with but little organic material, contrary to the MILIOLIDAE which obtain lots of organic substance. For the finer structure of the shell one can consult the works of WINTER[2]) and AWERINZEW[3]) on this matter.

The shell is always planispiral in young, especially in microspheric forms. In megalospheric forms the shell begins with a proloculum, followed by a neck-chamber (A_1), which in its turn is followed in some cases by a circumbanient chamber (A_2). In the highly developed forms the later chambers are divided into chamberlets and may become annular or uncoiling. Especially

1) CUSHMAN, J. A., Foraminifera (Sharon, 1928, p. 216).
2) WINTER, F. W., Zur Kenntniss der Thalamophoren (Arch. f. Prot., vol. 10, 1907, pp. 35—42).
3) AWERINZEW, S., Über die Struktur der Kalkschalen mariner Rhizopoden (Zeitsch. f. wiss. Zool., vol. 74, 1903, pp. 478—490).

in B-forms, but also often in A_1-generations the chambers immediately following the embryonic apparatus, are not divided into chamberlets. The aperture shows the most primitive shape in A-forms and is most complicated in B-forms.

From the 13 genera mentioned by CUSHMAN, we have to abolish the following ones: 1. *Dendritina*; 2. *Spirolina*; 3. *Monalysidium* (?); 4. *Sorites* (?); 5. *Amphisorus* (?).

Marginopora must be removed from this family and most probably be placed into that of the ANOMALINIDAE.

On the other hand I believe it will be much clearer and simpler to drop the ALVEOLINELLIDAE as a separate family and to join it to the PENEROPLIDAE: they are real peneropline organisms. I have suggested, when dealing with *Alveolinella*, that there is no reason to separate this genus from real *Alveolina* s. s. (= *Borelis*), so that *Alveolinella* must be dropped as a separate genus.

CUSHMAN, in his handbook on the Foraminifera (1928) has suggested, when dealing with trimorphism, that the three forms occurring in one species would show a different development, the microspheric form showing three stages of development, the A_1-form two and the A_2-generation one single stage of growth. As in the PENEROPLIDAE the occurrence of generations, considered by me as trimorphism, has been stated very clearly, one would be very anxious to know if here such a development into stages could also be traced, for CUSHMAN pointed out, that the adjustment of these stages is of considerable value for systematical purposes, saying (p. 359):

"So in the case of other groups if all three forms seem to show different generic characters, there is difficulty, but if one generic character is involved, the generic problem is not difficult. It may be shown, that when all three forms occur without the addition of a new character, a primitive form is under observation. In the microspheric form which shows several stages, it may be safely assumed that they are taken on in the order in which they once developed, and that they represent more primitive genera which are already known or are to be looked for in either the recent or fossil series. A classification built on this basis, as is the one here, must be close to the truth of the actual development of the different groups".

Now we will reconsider the different genera of the peneropline group, with these ideas in mind.

In the genera and species we observe:

1) Forma B: proloculum simple, without neck chamber, not possessing pores.
Forma A_1: proloculum with spiroline neck, with pores.
Forma A_2: in simpler species proloculum as in A_1, in more highly developed ones without pores, and in the most highly developed species with a circumbanient chamber.

Conclusion: the pores of the proloculum of A_1 must not be considered as primitive and as the B-form also does not possess them, they have no real systematical value. But as all species possess these pores, this characteristic must be of old age.

It is however possible that we have to consider them as cenogenetic.

2) The first sets of chambers of the microspheric forms of all species form a narrow planispiral, the so-called peneropline spiral, which is followed by a development of chambers, typical for the genus to which the species belongs. In cases, in which a highly developed form is studied, a third form of chambers has also been met with.

If we consider the microspheric forms of the different species and genera described in the following pages, we can easily find four stages:

a. Proloculum = P.

b. Peneropline spiral (occurring in the whole family) = Fam.

c. Generic development = Gen.

d. Specific development = Spec.

In forma A_1, we may, according to CUSHMAN's views, meet with the stages P., Gen., Spec., and in forma A_2 with P., Spec.

Now we can analyse the different species.

a) *Peneroplis pertusus.*

Forma B: Fam.: Peneropline spiral; in first whorls aperture simple.
Gen.: Peneropline spiral; in later whorls aperture a row of openings.
Spec.: Fanshaped spiral; in last formed coils aperture more than a single row

Forma A_1: Fam.: —
Gen.: Peneropline spiral; aperture a row of openings.
Spec.: Fanshaped spiral; aperture two rows of openings.

Forma A_2: Fam.: —
Gen.: —
Spec.: Peneropline spiral, aperture dendritical.

Therefore *Peneroplis pertusus* must be considered as a primitive member of the family, but with a long aera of development.

b) *Archaias discoideus.*

Forma B: Fam.: Peneropline spiral, 1 aperture pro chamber.
Gen.: Chambers equittant, later flaring, even annular, alar prolongations with apertures.
Spec.: Without secondary chambers.

Forma A_1 (?): Fam.: Peneropline spiral.
Gen.: Chambers equittant, later flaring.
Spec.: Without secondary chambers.

Forma A_2 (?): Fam.: —
Gen.: Chambers equittant, later involute (?)
Spec.: Without secondary chambers (?)

c) *Archaias aduncus.*

Forma B: Fam.: Peneropline spiral, 1 aperture pro chamber.
Gen.: Chambers equittant, except peneropline spiral of 20 chambers, later flaring and even annular.
Spec.: With secondary chambers, except peneropline spiral.

Forma A_1: Fam.: Short peneropline spiral of 13 chambers.
Gen.: Peneropline spiral is followed by equittant chambers, flaring later on, but scarcely becoming totally annular.
Spec.: With secondary chamberlets in later coils.

Forma A_2: Fam.: —
Gen.: Equittant chambers, flaring, never becoming annular.
Spec.: Secondary chamberlets throughout.

The genus *Archaias* shows many primitive characteristics. *A. aduncus* is more highly developed than *A. discoideus*.

d) *Praesorites orbitolitoides*.

Forma B: Fam.: Peneropline spiral.
Gen.: Fanshaped spiral.
Spec.: Cyclical chambers with partial chamberlets.
Forma A_1: Fam.: Peneropline spiral.
Gen.: Fanshaped spiral with partial chamberlets.
Spec.: Cyclical chambers with partial chamberlets.
Forma A_2: Fam.: Peneropline spiral very short or absent.
Gen.: Fanshaped spiral with partial chamberlets.
Spec.: Cyclical chambers with partial chamberlets.

Conclusion: *Praesorites* must be considered as a primitive species, its three forms showing the same characteristics except for the proloculum.

e) *Orbitolites marginalis*.

Forma B: Fam.: Peneropline spiral.
Gen.: Fanshaped and cyclical arrangement of chambers, with connection of chamberlets of the same row (Sorites-type).
Spec.: Cyclical chambers with connection of chamberlets of different rows only (Orbitolites-type).
Forma A_1: Fam.: —
Gen.: Fanshaped and cyclical chambers (Sorites-type).
Spec.: Cyclical chambers (Orbitolites-type).
Forma A_2: Fam.: —
Gen.: Fanshaped (few) and cyclical chambers (Sorites-type).
Spec.: Cyclical chambers (Orbitolites-type).

f) *Orbitolites duplex*.

Forma B: Fam.: Short peneropline spiral.
Gen.: Fanshaped and cyclical chambers (Orbitolites-type).
Spec.: High development of lateral chambers afterwards.
Forma A_1: Fam.: —
Gen.: Fanshaped spiral (short) and cyclical chambers (Orbitolites-type).
Spec.: Development of lateral chamberlets afterwards.
Forma A_2: Fam.: —
Gen.: —
Spec.: Only cyclical chambers, direct development of lateral chamberlets.

Orbitolites duplex shows a very high development in respect with Cushman's views.

g) † *Alveolina boscii.*

Forma B: Fam.: Peneropline spiral.
Gen.: Chambers overlapping as in *Archaias* (Archaias-type).
Spec.: Foramina highly developed into secondary chamberlets (Alveolina-type).
Forma A_1: Fam.: —
Gen.: Archaias-type.
Spec.: Alveolina-type.
Forma A_2: Fam.: —
Gen.: —
Spec.: Alveolina-type.

h) *Alveolinella Quoyi.*

Forma B: Fam.: Peneropline spiral.
Gen.: Archaias-type.
Spec.: Foramina of the Alveolina-type, later on divided into two, even into three rows above each other.
Forma A_1: Fam.: —
Gen.: Archaias-type.
Spec.: Very soon divided into three rows.
Forma A_2: Fam.: —
Gen.: —
Spec.: Foramina of the Alveolina-type, later coils possessing more rows of foramina.

Conclusion: Family-characteristics of *Alveolina* and *Alveolinella* are those of the other PENEROPLIDAE. Even the prolocula are of identical type. So the Alveolinae are real PENEROPLIDAE and do not form a separate family; generic characteristics of *Alveolinella* identical with those of *Alveolina*. So there is no reason to have a special genus for recent *Alveolina Quoyi*, called *Alveolinella*. (Yet, in my description, I have maintained this name, only to avoid confusion).

I. Genus **Peneroplis.**

Planispiral shells, beginning, especially in A-forms, with a chamber with porous walls, followed by a neck-chamber. Earlier chamberrows mostly involute, later chambers flaring or in a straight row. Wall of later chambers imperforate, with regular rows of pits. Aperture simple, or dendritic or divided into secondary foramina.

1. *Peneroplis pertusus* Forskål. Pl. LIII; Pl. LIV; Pl. LV, figs. 1—7.

Nautilus pertusus Forskål, Descr. Animale, 1775, p. 125, n° 65.
Peneroplis pertusus Jones, Parker and H. B. Brady, Foram. Crag., 1865, p. 19; H. B. BRADY, Rep. Voy. Challenger, 1884, p. 204, Pl. 13, figs. 16, 17.

General literature, in which the other "species" are also cited:

1. DREYER, F., *Peneroplis*; eine Studie zur biologischen Morphologie und zur Speciesfrage (Leipzig, 1898).
2. HERON-ALLEN, E. and EARLAND, A., The Foraminifera of the Kerimba-Archipelago (Trans. Zool. Soc. London, vol. XX, Part. II, 1915, pp. 594—604).
3. CUSHMAN, J. A., A monograph of the Foraminifera of the North Pacific Ocean, Part VI, Miliolidae (U.S. Nat. Mus., Bull. 71, 1917, pp. 84—88, textfigs. 8, 41 and 42, Pl. 36 and 37, figs. 1—6).

Synonyms:

a. *Peneroplis planatus* (Fichtel et Moll).

Nautilus (Lituus) arietimus (pars) Batsch, Conch. des Seesandes, 1791, p. 4, Pl. 6, figs. 15*a*, *b*.
Nautilus planatus, var. β. Fichtel et Moll. 1798, p. 91, Pl. XVI, fig. 1.
Peneroplis planatus Montfort, 1808—1810, Conchyologie systématique, vol. I, p. 258, 65me genre (erroneously named *P. lanatus*, see 2, p. 601, note).

b. *Peneroplis carinatus* d'Orbigny.

Foram. Américc. Mérid., 1839, p. 33, Pl. 3. figs. 7, 8.
Peneroplis dubius d'Orbigny, Foram. de Cuba, 1839, p. 62, Pl. 6, figs. 21, 22.

c. *Peneroplis arietinus* (Batsch).

Nautilus (Lituus) arietinus (pars) Batsch, Conch. des Seesandes, 1791, p. 4, Pl. 6, fig. 15*c*.
Peneroplis arietinus Parker, Jones and H. B. Brady, Ann. Mag. Nat. Hist., ser. 3, vol. 16, 1865, p. 26, Pl. 1, fig. 18.

d. *Peneroplis cylindraceus* (Lamarck).

Nautilus acicularis Batsch, Conch. des Seesandes, 1791, p. 4, Pl. 6, figs. 16*a*, *b*.
Spirolinites cylindracea Lamarck, Ann. du Mus., vol. 5, 1804, p. 245, vol. 8, 1806, Pl. 62, fig. 16.
Peneroplis cylindraceus H. B. Brady, Rep. Voy. Challenger, Zool., vol. 9, 1884, p. 205, pl. 13, figs. 20, 21.

In the following list the three forms of *Peneroplis* are indicated as A_1, A_2 and B in the usual way; the numbers before those letters indicate the quantity of specimens, found up.

Stat. 58. Anchorage off Seba, Savu, up to 27 m.; 2 A_1, 4 A_2.
Stat. 64. Kambaragi-bay, Tanah Djampeah, depth up to 32 m.; 12 A_1 (3 uncoiled), 1 A_2.
Stat. 71. Makassar and surroundings, up to 32 m.; 4 A_2, young.
Stat. 99. 6° 7′.5 N., 120° 26′ E., depth 16—23 m.; 2 A_2.
Stat. 104. Sulu harbour; depth 14 m.; 1 A_1.
Stat. 133. Anchorage of Lirung, Salibabu island, depth up to 36 m.; 4 A_1, 3 A_2 (1 uncoiled).
Stat. 164. 1° 42′.5 S., 130° 47′.5 E., depth 32 m.; 5 A_1.
Stat. 220. Anchorage off Pasir Pandjang, west coast of Binongka, depth 278 m.; 2 A_1 (1 uncoiled), 11 A_2, 1 B.
Stat. 226. 5° 26′.7 S., 127° 36′.5 E., depth 1595 m.; 1 A_1, 4 A_2, 1 B.
Stat. 252. West side of Taam-island; depth 9—36 m.; 1 A_2, young.
Stat. 262. 5° 53′.8 S., 132° 48′.8 E., depth 560 m.; 1 A_2.
Stat. 273. Anchorage off Pulu Jedan, east coast of Aru-islands (Pearl-banks), depth 13 m.; 1 A_1.
East-coast of Borneo, Balik-Papan-bay (leg. Prof. Dr. H. GERTH); 15 A_1, 5 A_2, 1 B.
Leksoela (Buru-exp., leg. Dr. H. TOXOPEUS); numerous A_1, A_2 and several B.

The species occurs at several stations, but is never very abundant, though station 262, 133, Balik-Papan and Leksoela procured splendid material. I also had the opportunity to study a sample of specimens, found in the intestine of a Holothurian from Naples.

The specimens were sectioned in the usual way and the initial chambers were studied first. Three kinds of initial apparates were found, and, when observing the shape of the shells containing those initial chambers, it at once was clear, that the trimorphism of this species was very obvious and that the polymorphism, so much discussed by other authors, was only due to trimorphism, as I will show here.

We will first give a short account of the views, hitherto met with in literature with respect to the different forms of our species.

As may be concluded from the enumeration of synonyms, older authors have considered the different forms as different species, even as different genera. This fact has been stated by CUSHMAN in his most recent work on general systematics of the Foraminifera [1]) and he divides the first subfamily of the PENEROPLIDAE called Spirolininae, into four genera:

1. *Peneroplis* Montfort (Conch. Syst., vol. 1, 1808, p. 259).
2. *Dendritina* d'Orbigny (Ann. Sci. Nat., vol. 7, 1826, p. 285).
3. *Spirolina* Lamarck (Ann. Mus., vol. 5, 1804, p. 244).
4. *Monalysidium* Chapman (Journ. Linn. Soc., Zool., vol. 28, 1900, p. 3).

The first genus, *Peneroplis*, shows the following characteristics:

"Test free, planispiral, close coiled in young, usually involute, in the adult becoming variously shaped, close coiled, flaring, annular or commencing to uncoil; chambers undivided; wall calcareous, imperforate except in the proloculum and sometimes the following chamber; aperture simple at the base of the apertural face, or long and slit-like, occasionally divided".

The second genus, *Dendritina*:

"Test similar to *Peneroplis*, the test usually thick, and showing a tendency to uncoil; aperture dendritic, in the apertural face".

The third genus, *Spirolina*:

"Test similar to *Peneroplis*, thick, early chambers close coiled, usually not completely involute, later ones uncoiled; aperture rounded, terminal".

The fourth genus *Monalysidium* must be something totally aberrant and has nothing to do with our genus *Peneroplis* s. s.

So we have only to consider the three first mentioned genera.

If we consult the beautiful figures on plate I of the work of DREYER, we can divide the 55 figures into three or four different groups.

First group: Test close-coiled, chambers embracing those of the preceding coils; mouth an irregularly shaped slit (dendritic) or rounded: figs. 1—4, 15—18, 26.

Second group: Test in the earlier coils close-coiled, later chambers arranged in a straight row; mouth like that of the first group: figs. 5—14, 19—25, 27—32.

Third group: Test in the earlier coils close-coiled; the chambers are flat, so that the whole spiral shows the tendency of becoming very thin. Later chambers in a straight row, some specimens forming a flat row of chambers, much more broad than high, but free at both sides, other specimens showing a tendency to become fan-shaped, the inner edge of each chamber being attached to the margin of the first coil. Mouth of different shape, in most cases becoming

1) CUSHMAN, J. A., Foraminifera; their Classification and Economic Use (Sharon, U. S. A., 1928, p. 217—218).

a single row of large foramina: figs. 33—35, 37—44, 47—55. There is every link between the two sub-groups, mentioned in this third group, not so between group I and II.

At first we must consider that all those forms, found by DREYER were dredged at one single station, Ras Muhamed near Sinai, Red Sea.

A study of the Naples-material at hand showed exactly the same forms. We have also studied the numerous samples of the Siboga-material, which contained also all forms and at more than one station they were all found together.

As one will observe immediately, these three or four groups are also enclosed in the genera, described by CUSHMAN, if we only consider the shape of the mouth and the way of coiling of the whorls. The thickness of the shell is not of very great importance, as I found that especially at some of the stations all shells were thick, at others thin. And, as we have mentioned already in the preface, the thickness of the outer shell is of no systematical importance. Yet we may remark, that especially shells, which were placed in group I, often possess very thick walls.

Other systematical works, which I have mentioned already, agreed in placing the different "species" in a single genus, *Peneroplis*, and so did DREYER.

Four species are mentioned [CUSHMAN, 1917 [1])].

I. *Peneroplis pertusus* (Forskål).

"Test planispiral, composed of several coils, central umbilical portion usually visible throughout the development of the test, chambers numerous, increasing gradually in height, but the test close coiled throughout; sutures somewhat depressed, wall marked by longitudinal, slightly oblique lines; apertures consisting of numerous slightly elongate pores, along the apertural face, the whole with a thickened lip. Diameter up to 2 mm.". It will be clear, that these forms are identical with those, figured by DREYER (figs. 47—55).

II. *Peneroplis planatus* (Fichtel et Moll).

"Test in the young close-coiled, becoming in the adult broad and complanate, the chambers increasing rapidly in height, wall ornamented with numerous longitudinal costae, broken at the depressed sutures; aperture consisting of a long, single row of small circular pores along the median line of the flattened apertural face". As we will show, this form ("the height of the chambers increases fairly early and is much flatter as well") is nothing else than a microspheric form and belongs to the same row of figures of DREYER's; especially fig. 55 is a very typical one in this respect.

III. *Peneroplis carinatus* d'Orbigny.

"Test planospiral, nautiloid, each coil completely covering the preceding to the umbilicus, test close coiled throughout, sutures usually strongly limbate; wall smooth; aperture consisting of numerous small circular pores scattered over the roughly triangular apertural face". "This form seems very different from most of the others, and seems more worthy of specific rank than the others included here". I have found it also in the Siboga-material and it will be discussed further on.

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1) In this work CUSHMAN is reserved, as to the specific value of the forms: "Besides this typical, planospiral, closely form, there are several different forms, which seem worthy of at least varietal distinctions".

In his work on the Philippine Foraminifera (U. S. Nat. Mus., Bull. 100, vol. 4, 1921, pp. 481—483) the varieties are considered as different species, and, as we have seen already, in 1928 some of them are separated as different genera.

IV. *Peneroplis arietinus* (Batsch).

"Test planospiral in its early stages, later becoming uncoiled and building chambers in a linear series, in transverse section elongate elliptical, wall longitudinally striate, aperture consisting of an irregular series of pores in the middle line of the apertural face".

This description is that of the specimens figured by DREYER in figs. 1—44. As I point out here, the aperture does not always consist of an irregular series of pores in the middle line, but, as I will show later on, some of the forms figured by DREYER show a typically dendritic structure, others possess apertures with the appearence of a sieve-like perforated plate. During my own researches, it struck me as very peculiar, that none of the modern authors, discussing the systematics of *Peneroplis*, viz. HERON-ALLEN, DREYER, CUSHMAN, considered the shape of the initial chambers. Yet WINTER [1]) discussed amply the difference between micro- and megalospheric shells, which could have been a hint to further investigations on this point. But WINTER did not solve all these questions as I have already mentioned in the introduction to part II, p. 93.

So I made a large quantity of slides through the different forms I met with. After having thoroughly figured them with the drawing-apparatus, they were ground. I made a very striking discovering: the different forms were apparently due to trimorphism.

Description of the three generations.

Forma A_1. Embryonic apparatus (megalosphere + neck chamber) very large 90 μ × 60 μ. Walls of the sphere perforated. Following rows of chambers narrow, very slowly increasing in height. The spiral remains a convolute one and the chambers of the later whorls embrace those of the preceding coils. Walls outside smooth or with rows of little pits or with ridges. Chamberwalls, especially those between two succeeding chambers and at the base of each chamber, very thick, especially in the later coils.

In young specimens the aperture is a triangular opening at the base of the last chamberwall; in older specimens it becomes dendritic.

Some specimens show the tendency to involute growth; in this case the following chambers have the volume of those of the last involute coil. The aperture of involute forms is a single row of foramina or there may be a circle of secondary foramina. In the case of a single aperture, which occurs especially in the first chambers of the straight row, the aperture is typically dendritic.

In all the specimens the wall is thick.

Forma A_2. Embryonic apparatus not large: 65 μ × 50 μ. Walls of the sphere not always perforate. Following rows of chambers increasing in height.

Some specimens show a tendency to uncoil; in that case the last row of chambers is flattened, but the height of the succee-

1) WINTER, F. W., Zur Kenntniss der Thalamophoren; I, Untersuchung über *Peneroplis pertusus* (Forskål) (Archiv für Protistenkunde, vol. 10, 1907, pp. 26—35, textfig. C).

ding chambers increases but slowly. In these specimens the first chamber is relatively small; there is not any peculiarity in the embryonic apparatus in those uncoiling specimens described under A_1.

Most specimens however do not uncoil, but the height of the chambers of the last coil increases very rapidly. The shell becomes flaring, fanshaped. Aperture a row of pores in these full-grown specimens.

It could be stated, that the chamberwalls of the uncoiling specimens are thicker than those of the flaring ones.

Forma B. Some specimens were not to be distinguished from those megalospheric flaring specimens mentioned under A_2, except with respect to the first rows. They have been completely described by WINTER [1]) and it is not necessary to give a detailed description here.

The first chamber shows neither a spiroline neck, nor a perforation and the following coils increase but slowly.

Conclusions.

Trimorphism in *Peneroplis pertusus* is a fact. It has already been suggested by RHUMBLER, who thought that the megalospheric specimens, determined by WINTER as "Peneroplengreise" could only be specimens, forming megalospores [2]).

Measuring the megalospores, figured by WINTER in his sporulating microspheric individual, most of them show a diameter of $80\,\mu \times 60\,\mu$ (inward measure). So we may conclude, that the megalospheres of WINTER are identical with those, described as our forma A_1. This agrees with our views on trimorphism: those forms, which are not mentioned by WINTER in forming microspores, viz. the convolute ones, are the "Peneroplengreise".

In some of the samples, especially in that of Balik-Papanbay very peculiar specimens of the convolute type were found. Their outer chamberwalls were eroded, so that the interior of those chambers could be seen. Yet the other Foraminifera in this sample, even the PENEROPLIDAE, were well preserved. It is very probable, that these defective shells had just formed megalospores, for, as WINTER showed for the microspheric generation, the shell is partly dissolved to allow the megalospores to pass. These megalospores, measuring $65 \times 50\,\mu$, form the flaring types, also described by WINTER; they form microspores. Here we have shown, that the first megalospheric generation is that with the larger megalosphere, the second that with the smaller one. It is probable that this is the case in much more genera of the Foraminifera, though in *Pulvinulina* it is quite the reverse. But once more: trimorphism is the result of this heterogamy!

RHUMBLER [3]) was the first to discover the pores of the embryonic megalospheric chamber and suggested that these pores have a respiratory function: "Denn diese Brut bildet sich ihre Embryonalschale schon im Inneren des Mutterkörpers, und sie musz deshalb ihren Athem-

1) WINTER, l. c., Pl. I, fig. 1.

2) RHUMBLER, L., Foraminiferen der Plankton-Expedition (vol. I, 1911, p. 324, note).

3) RHUMBLER, L., Über die phylogenetisch abfallende Schalen-Ontogenie der Foraminiferen (Verh. Deutsch. Zool. Gesellsch. 1897, pp. 170, 183, figs. 12—14).

Sauerstoff während des Aufenthaltes im Mutterkörper durch zwei Schalen, durch die Mutter und durch die eigene Embryonalschale, hindurch beziehen".

The same explanation has been given of the ridges, which form the only structure of the shell (p. 184): "die Grübchen sollen offenbar die Athmung durch die Schale hindurch erleichtern; ich glaube nicht, dasz sich für sie irgend eine andere Function als plausibel erweisen liesze".

The biformism of the shell, which is found in the typical uncoiling specimens, must be due, concludes RHUMBLER, to the thickness of the shell and the difficulty of respiration. It is very probable that RHUMBLER is quite right, for the flaring types show always very thin walls.

The different shape of the three forms A_1, A_2 and B must be due to different surface-tension and inner constitution of the protoplasm. It is very likely, that the flaring chambers, especially of the megalospheric A_2-forms, are necessary for the forming of the spores, as we have suggested already in the introduction.

I wish to discuss here the peculiarities of the apertures in the different forms, as these peculiarities have lead to the erection of several species and even genera (f. i. *Dendritina*). The first chambers of the microspheric specimens show a triangular mouth, which is lengthened with the increase of height of the chambers, and denticulations at both sides of the aperture divide it into different parts. Later on these denticulations become bridges and pairs of secondary foramina are visible; in the flaring chambers a single row of secondary foramina appears.

In most specimens of the A_2-form the last chamber shows the double row of foramina. In the A_1-form the aperture of the adult is a simple slit, or it forms denticulations, which, especially in the thick-walled forms, give rise to the dendritic aperture. In some forms, in which the last row of chambers becomes evolute, the aperture forms large denticulations, which, in the extreme case form two rows of openings, arranged in a circle.

The shape of the shells of the three forms shows a typical gradation, in an evolutionary sense, and so the ideas of CUSHMAN's[1]) are illustrated here once more:

The microspheric form shows firstly a microsphere, followed by a simple convolute spiral of chambers; afterwards a flaring spiral is formed; the A_2-form shows the typically milioline beginning, followed by convolute and flaring spiral; the A_1-form is only convolute, never flaring.

If CUSHMAN's views are right, the milioline megalosphere (with its spiroline neck) must be looked upon as an adaption, not as an atavism. So the PENEROPLIDAE cannot be arranged in the neighbourhood of the MILIOLIDAE, as older authors do, but there is some probability that they are allied to the forefathers of the NUMMULITIDAE.

So we come to the conclusion, that all forms, figured by DREYER in his figs. 1—55 belong to the same species, *Peneroplis pertusus*; that the species *P. planatus*, *P. carinatus*, *P. arietinus* and *P. cylindraceus* must be considered as synonyms of *P. pertusus*; that the genera *Spirolina* and *Dendritina* do not exist.

II. Genus **Archaias.**

This genus, known ordinarily as *Orbiculina* Lamarck, has lately been called *Archaias* by CUSHMAN[2]), as he has pointed out, that MONTFORT's *Archaias spirans* is a real *Orbiculina*.

1) CUSHMAN, J. A., The Foraminifera (Sharon, 1928, p. 357—360).
2) CUSHMAN, J. A., The Foraminifera (Sharon, 1928, p. 220).

MONTFORT's "Conchiologie systématique" appeared in 1808, LAMARCK's "Encyclopédie Méthodique" in 1816. So MONTFORT's name has the priority.

The description of the genus *Archaias* has been given by CUSHMAN as follows:

"Test in the early stages planispiral and lenticular, bilaterally symmetrical, in later stages becoming flaring, even annular; wall imperforate, divided into chamberlets; apertures in several rows on the apertural face.

Miocene to Recent".

Only one single recent species, *Archaias aduncus* (Fichtel et Moll) has been described in literature. I was able to show in this monograph, that there occurs another living species, though very rarely distributed, which can be distinguished from *A. aduncus* by the lacking of any trace of secondary chamberwalls, so that one would expect it to be some *Peneroplis*. All characteristics, typical for *Archaias*, are also present in this new species, already known as *Peneroplis pertusus*, var. *discoideus* Flint [1]), except for the chamberlets. So we must drop in CUSHMAN's description: "divided into chamberlets". Then, however, some forms of typical *Peneroplis* would easily be arranged, though erroneously, within the genus *Archaias*, and therefore we have to mention some other characteristics to avoid such an error. The chambers of the earlier coils in *Archaias* become very soon extending over the test to the umbilical region, forming an involute test. But the apertural face of these involute chambers is a very typical one with respect to those of the involute forms of *Peneroplis pertusus* known as var. *carinatus* (see my description of that species). As I have already mentioned, the apertures of those carinate forms of *Peneroplis* are generally dendritic, and are only met with in the central part of the triangular apertural face. In *Archaias discoideus* however, the apertures are arranged in a regular row of slit-like pores, which are, at equal distances, found especially in the alar parts of the apertural face of involute chambers. This is a very clear and typical difference. In *Archaias aduncus* the slit-like apertures are replaced by two rows of pores, surely derived from the slit-like ones by overbridging the middle part.

The microspheric forms of *Peneroplis* never show the tendency to become involute. In all known forms of *Archaias* however, the microspheric specimens are always involute in early stages. This is a second sharp difference between these two genera.

A third difference may be found in the texture of the chamberwalls. *Peneroplis* possesses furrows, directed transversely to the breadth of the chambers, or rows of furrows in that direction. In *Archaias* on the other side the texture is typical orbitoline, showing an irregular mashwork on the walls. But in some forms the wall seems to be smooth.

So we can give the following description of the genus *Archaias*:

Test planospiral, chambers numerous, with alar prolongations extending over the older coils to the umbilical region, involute. Later chambers in some forms becoming uncoiled, so that the shell is fan-shaped or even discoideal. Chambers with many foramina, not only in the triangular centre, but also in the alar parts of the chambers. In some species the chambers are divided into chamberlets by secondary walls between the foramina. In

1) FLINT, J. M., Recent Foraminifera (Report U. S. Nat. Mus., 1897 (1899), p. 304, Pl. 49, fig. 1).

the A-forms the proloculum is typical peneropline, with fine pores. B-forms are always involute in the first coils. Texture of the walls an irregular mashwork, so that the wall becomes pitted.

There are only few species of *Archaias* (= *Orbiculina*) mentioned in literature. Most of them are forms of the species *A. aduncus* (Fichtel et Moll), viz. *A. angulatus* (Fichtel et Moll), *A. compressus* (d'Orbigny), *A. flabelliformis* (Brady). I believe it is quite right to consider them as forms of one single species, *A. aduncus*, as LISTER [1]) did. BRADY (Challenger Report, p. 209), was wrong when considering them respectively as very young, young and adult conditions, as one can easily state, when studying their inner structure. But it must be pointed out, that the name *A. compressus* of D'ORBIGNY was originally given to those forms, which possess a circular or nearly circular shell. I suggest these forms to be adult A_1- or B-forms, in analogy with *Peneroplis*. So BRADY is inclined to abolish this name *A. compressus*, as "the fact is, that wherever *Orbiculina* abound the whole range of contours figured in Pl. XIV may almost always be met with — the embracing or involute spiral, the explanate or evolute, the crosier-shaped, the fan-like, and the discoidal, together with a number of gradational stages".

There are many reasons to believe, that these forms are due to trimorphism, as LISTER himself pointed out already, that the prolocula of these different forms do not possess the same average of diameter:

aduncus:	megal.	117 μ.
compressus:	„	109 μ; microsph. average 18 μ.
flabelliformis:	„	64 μ.

The outer shape of these forms shows the same characteristics as the forms of *Peneroplis pertusus*. Forma *compressus* is not known to be microspheric; of forma *flabelliformis* a single specimen "appears to be microspheric".

It is very remarkable, that LISTER (1903, p. 99) gives attention to the fact of "initial polymorphism" (now called trimorphism) in *Orbiculina*, saying:

"On examining the construction of the tests of small specimens, as displayed in section, a mode of variation of a different kind becomes apparent, one which illustrates the phenomenon of Initial Polymorphism described by MUNIER-CHALMAS and SCHLUMBERGER in *Idalina*. In the sample of sand which furnished the varieties above described were numbers of small megalospheric specimens resembling the young of the typical forms, but beginning in a megalosphere of small size. In the specimen represented in Fig. 31, A^1, the central part of one of these is seen in section. Here the megalosphere measures only 34 μ in diameter. Associated with the small size of the megalosphere of these forms is a long series of single chambers before the subdivision into chamberlets begins. In both characters they thus vary in the direction of the microspheric form, though always distinguishable from it by the presence of the spiral passage. In *Orbiculina* then, as in *Idalina* the construction of the early part of the test is correlated with the size of the megalosphere. If it is small the arrangement approaches that of the microspheric form, if large it departs more widely from it".

So I believe that trimorphism would be stated certainly, if a larger material of *A. aduncus*

1) LISTER, J. J., The Foraminifera; in: A treatise on Zoology, by E. R. LANKESTER (Part I, fasc. 2, London 1903, pp. 95—100).

could be studied. If trimorphism would be stated in *A. discoideus*, I do not know, but it is very probable, as the two forms I have met with, show the typical features of the two forms of *Peneroplis*, A_2 and B.

Therefore two different recent species can be mentioned, *Archaias discoideus* and *A. aduncus*, the former showing more primitive characteristics. It is peculiar, that LISTER (l.c., p. 100) describes some aberrant specimens of *A. aduncus*, in which the subdivision into chamberlets may be incomplete or totally absent. LISTER is inclined to believe, that they are degenerated forms, rather than representations of *Peneroplis* and so do I. I believe, that they have been described by CUSHMAN from the coast of Jamaica under the name *Peneroplis discoideus*. These forms show all the typical features of real *Archaias*, and I will describe them under the name *Archaias discoideus*.

Archaias aduncus can not be described in this monograph, because there was no material available. This is the more peculiar, as BRADY mentions it from the East Indian Archipelago and the Philippines. But CUSHMAN[1]) says about this occurrence: "I have found this species at but two stations in the Philippine region. The species is rare at both stations. BRADY records this form about the various East Indian Islands, but I have failed to find it in the North Pacific except at one station. It did not occur in the material I had from about the Hawaiian Islands, and it seems to be very rare in the Indo-Pacific, being replaced by various species of *Orbitolites*".

Yet I can give a short critical record of this species as very good data are known now about its internal structure.

CUSHMAN describes the so-called species "*Orbiculina compressa* d'Orbigny" as follows[2]):

"There is an oval proloculum with a thin wall of uniform thickness. The second chamber is elongate, closely coiling on the surface of the proloculum for about a half coil in length. Both the proloculum and this second chamber are finely perforate..... The third chamber is globular and connects with chamber 2 by a single aperture. Chambers 3 to 7 are of the same general character, and at this stage (in section at least) this might be the young of *Peneroplis*. Chamber 7 completes a single coil from the proloculum. This number of chamber is also very similar to the condition seen in the first coil of *Peneroplis*. Chamber 8 adds a new character, that of multiple apertures, there being two in this chamber. Chambers 8 to 12 each have two apertures. Chamber 15 has developed three apertures. As the chambers increase in height there is a corresponding increase in the number of the apertures. In the later development of the same specimen the chambers increase rapidly in height from the sixteenth to the twentieth...."

And about *Orbiculina adunca* (Fichtel et Moll) CUSHMAN mentions:

"This species in its early development is in most respects comparable to that of the preceding species, *O. compressa*, but is much more accelerated. There is in the megalospheric form, a large, nearly spherical proloculum, followed by an elongated chamber of a half coil in length. This second chamber is very low at its conception but widens gradually towards its apertural end..... The wall is perforate..... In *O. adunca* chamber 4 has two apertures, thus taking on here the character which was taken on in the specimen of *O. compressa* in the eighth chamber and in *Peneroplis* taken on much later than this, the sixteenth chamber in

1) CUSHMAN, J. A., Foraminifera of the Philippine and adjacent seas (U. S. Nat. Mus., Bull. 100, vol. 4, 1921, p. 485).
2) CUSHMAN, J. A., Foraminifera of the North Pacific Ocean, Part VI, Miliolidae (U. S. Nat. Mus., Bull. 71, 1917, p. 89).

SCHAĆKO's figure and in some specimens of *Peneroplis* never reached. *O. adunca* is then a much accelerated species".

As we have already shown, when dealing with *Peneroplis pertusus* and as we will show further on, dealing with *Orbitolites* and *Alveolina*, an acceleration, in comparison with A_1, is always found in forma A_2, and is no specific characteristic at all. As only this acceleration can be considered as the difference between *A. compressus* and *A. aduncus*, I am sure that the first is nothing else than the A_1-form of the latter.

It is however very probable that some forms of our species *Praesorites orbitolitoides* are described as *Orbiculina compressa*.

When studying the two species found in recent seas, one may easily distinguish *A. discoideus* as the more simple one. A transverse section shows its simplicity, as well as the lack of any trace of secondary chamberlets. As from *A. aduncus* some forms are known without chamberlets, an analysis of these forms would be very instructive, with respect to their systematical value.

Some authors have suggested, that *Orbiculina (Archaias)* showed in its earlier stages the features of *Alveolina*, thus forming a kind of missing link between that genus and *Peneroplis*. This must be wrong; *Alveolina* can never be derived from *Orbiculina*. Even the geological distribution of these genera opposes itself against that idea, *Alveolina* being found in Eocene strata, *Orbiculina* being known from off Miocene age.

1. *Archaias discoideus* (Flint). Pl. LVI.

Peneroplis pertusus (Forskål), var. *discoideus* Flint; Ann. Rep. U.S. Nat. Mus., 1897 (1899), p. 304, Pl. 49, figs. 1, 2; CUSHMAN, Publ. 291, Carnegie Instit., Wash., 1919, p. 69; CUSHMAN, Proc. U.S. Nat. Mus., vol. 59, 1921, p. 76, textfigs. 13—16, Pl. 18, fig. 20; Pl. 19, figs. 1—3.

Synonyms:

Peneroplis proteus d'Orbigny? Foram. de Cuba, 1839, p. 60, Pl. 7, figs. 7—11; CUSHMAN, Foram. north coast of Jamaica, Proc. U.S. Nat. Mus., vol. 59, 1921, p. 75, Pl. 18, figs. 13—19, textfigs. 13—16.

Peneroplis pertusus Forskål, var. *discoideus* Flint, Ann. Rep. U. S. Nat. Mus.. 1897 (1899), p. 304, Pl. 49, figs. 1, 2; CUSHMAN, Publ. 291, Carnegie Inst. Wash., 1919, p. 69; CUSHMAN, Proc. U.S. Nat. Mus., vol. 59, p. 76, Pl. 18, fig. 20, Pl. 19, figs. 1—3 (mentioned here as *Peneroplis discoideus* Flint).

In the Siboga-material only two specimens were found, but in pretty good condition, one of these turned out to be microspheric, the other megalospheric. In analogy with what I found in *Peneroplis*, the latter seemed to be an A_1-form. The Siboga station, at which the two specimens were gathered, was:

Stat. 220. Anchorage off Pasir Pandjang, west coast of Binongka, depth 278 m.

I will first give the description of the two specimens.

Megalospheric specimen.

Very like a fullgrown specimen of *Peneroplis pertusus* of fan-like shape, but the initial part of the shell largely involute. Later chambers flat and fan-shaped, but not becoming circular. Chambers of the involute part of the shell with rows of apertures at the alar prolongations of the chambers. Walls pitted by round furrows. Apertures of later chambers generally

two rows of openings, but of older chambers a row of transverse slits. Walls with an irregular network of secondary chalkmaterial.

Diameter first chamber 50 μ. Diameter shell ± 1,7 mM.

Microspheric specimen.

Large specimen beginning with an involute spiral, but the chambers, though remaining involute, become flaring at one end, so that finally a fan-shaped and even discoidal shell is formed, in which the chambers can form annules. In this case these annular chambers are not involute at one of their ends. First chamber round, 16 μ diameter, followed by a peneropline spiral of simple chambers, the 20th chamber having more than one aperture, the preceding ones with simple foramina. Apertures of flaring chambers numerous in irregular rows; of older chambers in a simple row of slits. Walls pitted, as in megalospheric form.

In both forms no traces of secondary chamberlets are to be seen.

It seems that the only difference between *A. discoideus* and *A. aduncus* can be found in the lack of secondary chamberlets, for, as will be seen at once, all other structural features are also found in LISTER's description of *A. aduncus*, even the fact, that in the microspheric specimen there are at the beginning some twenty simple chambers, communicating by a single aperture [1]).

I believe some forms, described already as *Peneroplis*, must be regarded as belonging to this species. The species, mentioned by FLINT as *P. pertusus* var. *discoideus* (l. c., p. 304) very probably is the same as our *Archaias discoideus*. It was found at the Kei-islands, and shows in section the typical habitus of megalospheric form, and his figure 1, Pl. 49 shows the involute beginning of the shell as well as the irregular foramina. He himself says about it: "thin disk, resembling the discoidal forms of *Orbulina* but distinguished by the entire absence of septa in the individual chambers". This description shows clearly, that *Archaias discoideus* and FLINT's *Peneroplis discoideus* must be identical. The typical characteristics of *Archaias* however, can be found completely in this "*Peneroplis*" *discoideus*. So I thought it best, to call it *Archaias discoideus* (Flint). CUSHMAN in his articles cited above has described younger forms of the species, as *Peneroplis discoideus* Flint, but mentions also from the West Indias a very abundant species, *Peneroplis proteus* d'Orbigny. The involute beginning of the shell and the flaring later chambers are so very typical, that I do not hesitate to designate them as some form of, probable megalospheric, *Archaias discoideus*. With respect to what we have observed, dealing with *Peneroplis pertusus*, this *Peneroplis proteus* d'Orbigny may be the megalospheric form with large embryonic chamber (forma A_2). But further investigations must clear up the matter. It is however very peculiar that both forms, *Peneroplis discoideus* Flint and *Peneroplis proteus* d'Orbigny, have been found together at station 4, Montego bay.

Discoidal forms are mostly microspheric ones, so they are relatively rare.

III. Genus **Praesorites.**

This genus has been erected by H. DOUVILLÉ in his memoir: Essai d'une révision des Orbitolites (Bull. Soc. Géol. de France, ser. 4, pt. II, p. 289, 1902).

CUSHMAN (1928, Foraminifera, p. 221) gives a short, but excellent description of the genus:

1) LISTER, J. J., The Foraminifera, l. c., 1903, p. 99.

"Test in the early stages planispiral, at least in the microspheric form, later annular; chambers in a single plane, not completely divided into chamberlets; apertures numerous; cretaceous".

DOUVILLÉ has observed: "deux rangées d'ouvertures et un commencement d'endosquelette, sous forme de cloisons transverses qui se complètent peu à peu" [1]).

I have studied the figures and descriptions of DOUVILLÉ as well as some fossil material and have no doubt, that the recent material I could observe belongs to the same genus and it is very probable, that it even is the same species, which DOUVILLÉ has mentioned as the type of his genus *Praesorites*.

With respect to its systematical place we can add, that the genus must be very closely allied to *Peneroplis*, so much, that at first I was inclined to call it *Peneroplis*. But, as obviously DOUVILLÉ has described the same genus and called it *Praesorites*, I will preserve this name, though, as I will point out further on, the genus *Sorites* itself must be dropped.

It is a very peculiar fact, that this genus, considered as a cretaceous one, still lives in recent times. As I have already mentioned, the species I am to describe is not distinguishable from that, found by DOUVILLÉ in the cretaceous.

1. *Praesorites orbitolitoides* n. sp. Pl. LV, figs. 8, 10 and 11; Pl. LVII, figs. 4 and 6; Pl. LVIII; Pl. LXI, figs. 3 and 14.

This very peculiar species seems to be a rare one. In the Siboga-material it has been found only at one single station:

Stat. 213. Saleyer-anchorage; up to 36 m.; between coral-sand.

and only in few, though very typical, specimens.

These specimens were all of the A_1-form. But I had the opportunity to study abundant material from the gulf of Mexico. I have greatly to thank Dr. MORTENSEN for his kindness of procuring me that material, which enabled me to study the species in all its forms.

The species has been figured by FLINT [2]), who describes it as belonging to *Orbitolites marginalis*, from which, however, it can easily be distinguished by its partial, secondary chamberwalls in the first coils. It was gathered at Florida, Key West and Cape Fear."

RHUMBLER has given an excellent figure in his description of the Foraminifera of the Plankton-Expedition [3]).

The shell forms a flat, very thin, round disk of white colour. In most cases it shows an inner part, which is more hyaline, abruptly followed by much more opaque rings, while the outer margin once more is thin and hyaline. Diameter of the shells up to 4 mm.

Description of the three forms:

Forma A_1. Proloculum of $\pm$ 50 μ followed by a neck chamber. Both (?) are perforated by fine pores. The neck is tubular but its diameter increases towards the end. Then 6—10 chambers are following, totally undivided and showing nothing but peneropline characteristics. These chambers are followed by a large series in which traces of

1) DOUVILLÉ, H., Evolution et enchaînements des Foraminifères (Bull. Soc. Géol. de France, ser. 4, vol. VI, p. 595).
2) FLINT, J., Recent Foraminifera (Report U. S. Nat. Mus., 1897, p. 304, Pl. 51, fig. 1).
3) RHUMBLER, L., Die Foraminiferen (Thalamophoren) der Plankton-Expedition, vol. I (1911, Pl. XII, figs. 14, 15 and 16).

secondary chamberwalls are developed. These traces begin at their basal walls, but soon they become very thin and at the middle of the chamber they vanish completely. They find their analogon in *Heterostegina operculinoides* Hofker. The outer walls of the whole shell show fine round furrows, giving the impression of perforation. These furrows are homologous with those, described in *Peneroplis pertusus*.

Forma A_2. This form can be distinguished from the former by a somewhat larger proloculum ($\pm$ 65 μ), followed by a large neck. There are only two or three peneropline chambers, followed by the typical ones with partial secondary walls. The centrum of the shell is provided with furrows.

Both forms, A_1 and A_2 begin with a peneropline arrangement of the chambers, which increase gradually, become fanshaped and then even annular. These annular chambers show a very peculiar position of the foramina. Each chamberlet communicates with the next ones of the same row by a large passage, which derives from the large opening, shown in the older rows. These passages in their turn open into a chamberlet of the following row, so that these first mentioned chamberlets also open into those of the following row. The same phenomenon can be stated in *Orbitolites marginalis* (Forma A_1 and B). So I must point out, that the arrangement of the foramina cannot be of generic value, as we can observe it changing gradually. In *Peneroplis* the foramina from simple become multiple; in *Praesorites* the foramina soon become multiple and then form between each other partial secondary walls; in these walls there remain openings, which can serve also as a passage to the outer world (apertures); in *Orbitolites marginalis* (= *Sorites*) the condition may be that of *Praesorites*, but in some forms (Forma A_2) the chamberlets can form separate passages through the secondary walls, opening each into the outer world. In *Orbitolites duplex* the foramina always attain this height of development and in some forms of this species the foramina are divided into rows, situated vertically to the plane of the shell; this is a rule in *Orbitolites complanata* (*Omphalocyclus*) in which the passages give rise to superficial layers of chamberlets.

Forma B. This form is characterised by its small proloculum (16 μ) followed by a typical peneropline spiral; only when twelve or more chambers have been formed, the partial secondary walls can be found. In some cases the first spiral becomes a straight row of chambers and then, the breadth of the chambers increasing, they grow gradually annular.

The species seems, as I have mentioned already, a rare one. Yet it has already been observed by some authors, viz. by CUSHMAN, who describes it under the name of *Archaias* (*Orbiculina*) *aduncus*, var. *compressus* (Foraminifera from the North Coast of Jamaica, United States Nat. Museum, Proceedings, vol. 59, 1921, p. 76). When comparing his Pl. 19, figs. 1 and 2 with my material of *Praesorites*, I could not find any difference. So I asked Dr. CUSHMAN to send me some material from type localities. He kindly sent me a beautiful collection of his *Archaias compressus* and *Archaias aduncus* from Bermuda and from Dry Tortugas, Florida. So I could state, that in these localities occurred the three forms of *Archaias aduncus*, one

of which is known in literature as *A. compressus*, but several specimens of forms, labelled by CUSHMAN as *A. compressus*, showed to be nothing else than *Praesorites orbitolitoides*, which can be distinguished by its imperfect chamberlets, when young.

I have to point out, that *Praesorites* can not be closely related to *Archaias*, as the typical involute growth of the first sets of chambers has already been found in *Archaias discoideus*, which shows no traces whatabout of secondary chamberlets.

IV. Genus **Orbitolites.**

The species of this genus have been subject to many controverses and as we will show here, the systematics of these species have never been clearly understood.

CUSHMAN (Contrib. Cushman Laboratory, vol. 3, 1927, p. 123) says, that "the genus *Orbitolites* must have a more restricted use than has often been made of it". Its genotype, *O. complanata* Lamarck, from the Paris eocene beds is really very poorly known, especially with respect to its structure. It is very probable, that a more detailed study of its internal structure will show us, that this *O. complanata* belongs to another genus, *Marginopora*, or, more precisely: *Marginopora* is a real *Orbitolites*, while our recent *Orbitolites marginalis* and *duplex* must be called otherwise [1]). Anyhow, as I will show further on, recent *Orbitolites complanata* does not exist.

It was CARPENTER, who gave an excellent study on the anatomy of the shell, distinguishing three species, *Orbitolites marginalis*, *O. duplex* and *O. complanata*. According to this author they were mainly distinguishable by two characteristics. In *O. marginalis* a transverse section shows the chamberlets simple and the foramina are situated in a single row along the margin. In *O. duplex* the chambers in transverse section are simple, but they show two foramina each; in *O. complanata* the chambers show outgrowths, the superficial chamberlets, and possess oblique foramina in a large number. (As I will point out *O. complanata* does not exist as a species).

The central part of the shell has not been taken into consideration.

The fourth species of CARPENTER, viz. *O. tenuissima*, cannot be an orbitolite species at all, as has been pointed out by CUSHMAN and others. (It has been called *Discospirina* by modern authors).

As HERON-ALLEN and EARLAND pointed out, it is very difficult however to distinguish the three forms, especially *O. marginalis* and *O. duplex*, by means of the situation of the marginal foramina. Therefore CUSHMAN proposed another characteristic, the structure of the first sets of chambers, especially of megalospheric forms. But knowing now, that the megalospheric forms in most Foraminifera show two kinds of architectonics, and are distinguished as forma A_1 and A_2, it is obvious, that the characteristics of the megalospheric apparatus never can be of any systematical value, if not two forms in each species are known. I am sure, the facts must be interpreted otherwise and CUSHMAN gives a hint in that direction, pointing out, that in the philippine collections "both species often occur together in various stages of development".

As we have shown here briefly, that it is very difficult to distinguish the species of

1) Recent study of material deriving from the Eocene of Paris has shown me, that LAMARCK's species shows the real structure of our *Marginopora*. I will deal with this subject, however, in another publication.

Orbitolites, there remains to inquire whether the definitions of the species, given by CARPENTER, are right.

For this reason I studied many hundreds of specimens of the Siboga-collection, gathered at different stations. I stated the remarkable fact, that the specimens of *O. complanata* from two different stations, 64 and 96 (the first station situated at Djampeah-islands, south from Celebes, the other north from Celebes) were very differently shaped. Those from station 64 were thin, especially in the middle of the test, showing all chamberlets, the others on the contrary possessed thick tests, with irregular chalk deposits at their centre, so that here the chambers were not visible. (These forms, like those from station 96, are described here as *Marginopora vertebralis* Quoy et Gaimard).

In particular between the microspheric specimens there are great differences. Those from station 64 are flat and large, those north from Celebes are of the "variety lacineata". This microspheric "variety" is also known from the Fiji-islands and Tonga (studied from the Brady-collections by LISTER).

I made transverse slides of all forms I could distinguish and these slides were treated with the canadabalsam-method, which gave very beautiful results and at once the very obscure systematics of *Orbitolites* grew clear: CARPENTER's and others' species of *Orbitolites* are only forms of three different species, but so mingled together, that nobody was able to give a definition of each of the species.

We have to distinguish two species of *Orbitolites*, *O. marginalis* and *O. duplex* and a single species of *Marginopora*, *M. vertebralis*, all living now in tropical and subtropical seas. I will maintain these three names to avoid further confusion, but the description of these three species must be thoroughly changed.

But first we will give a description of the genus *Orbitolites*, because here also some confusions must be obviated.

If we examine the beautiful publication of FLINT [1]) on the Foraminifera gathered by the "Albatross" we must look at his figure 1, Plate 51: *O. marginalis*. The first chambers of these specimens show a typical peneropline shape, not being divided into secondary chamberlets. I have studied some poor material of this form, from the Siboga collections, but a very large one, gathered by Dr. MORTENSEN in the gulf of Mexico, and came to the conclusion, that this species must be different from *Orbitolites* and must be placed in the neighbourhood of *Orbiculina* (see the chapter on *Praesorites*). This being the case, we have now the opportunity to border the genus *Orbitolites* very sharply and the species belonging to this new-bordered genus have got the right to dwell in a genus, quite different from *Peneroplis* and *Orbiculina*. It was pointed out already by CUSHMAN in his sharp definition of the first sets of chambers of *Orbitolites*, that all chambers, following the initial one, are divided into chamberlets, but he has overlooked FLINT's mistake. It is probable, however, that also other authors, thinking to deal with *O. marginalis* in reality dealed with this species of *Praesorites*. But if we call into mind CUSHMAN's textfigure 47 [2]), we never can confuse these two species.

So we may describe the genus *Orbitolites* in the following way:

1) FLINT, J. M., Recent Foraminifera (Report U. S. Nat. Museum, 1897—1899).
2) CUSHMAN. J. A., U. S. Nat. Mus., Bull. 71, 1917.

Test discoidal, in some cases lacineate at the margin, early chambers following the initial one (which often shows a *Cornuspira*-like neck, imitating a second chamber in some cases) divided directly into secondary chamberlets, except the first one. Chambers soon becoming annular. Most of the chamberlets possessing two or even more apertures. Test in all cases imperforate, but sometimes showing the tendency to develop structures as are also found in *Peneroplis* and which may even imitate coarse pores.

1. *Orbitolites marginalis* Lamarck. Pl. XLI, fig. 1; Pl. LV, fig. 9; Pl. LVII, fig. 3; Pl. LIX; Pl. LXI, figs. 1, 2, 7.

For literature one may consult CUSHMAN's works:

U. S. Nat. Mus., Bull. 71, p. 92 and U. S. Nat. Mus., Bull. 100, vol. 4, p. 484.

We must remark however, that most descriptions of and references about *O. duplex* must be considered as made about *O. marginalis*, for my *O. marginalis* and the *O. duplex* of most other authors are synonyms.

I have to refer to the beautiful description of *O. duplex* (*O. marginalis*!) of RHUMBLER [1]), in which many figures show the typical characteristics [2]).

The species is not very abundant in the Siboga material. It has only been found in about fifty specimens at:

Stat. 43. Anchorage off Pulu Sarassa, Postillon Islands, up to 36 m., attached to algae.

It is a remarkable fact, that it has not been met with at any station, where other species of *Orbitolites* were abundant. It occurred in four specimens at:

Stat. 142. Anchorage off Laiwui, coast of Obi Major; 23 m.

but no where it showed the abundance which is mentioned from the Red Sea.

Now will follow the description of this primitive Orbitolite:

Forma A_1. First chamber with diameter of ± 160 μ, followed by *Cornuspira*-like neck. Chamberwall with real fine pores. Second chamber ovoid, third chamber with two or three chamberlets, followed by a set of about twelve chambers, forming a peneropline shell, but soon afterwards the chambers show the typical orbitolite, circular arrangement. Some chamberlets show two foramina at each outer edge of the chamber, so that two foramina of adjacent chamberlets often fuse together. But as in most annules the chamberlets possess a third foramen leading to the following row and each foramen opens into a different chamberlet of the following annule, the arrangement of the chamberlets of a row in comparison with that of the next rows

1) RHUMBLER, L., Die Doppelschalen von *Orbitolites* und anderer Foraminiferen vom entwicklungsmechanischen Standpunkt aus betrachtet (Archiv für Protistenkunde, Vol. 1, 1902).

2) It is very probable, that some authors have described some forms of *O. marginalis* under the name *Sorites marginalis*. I do not see why there would be the necessity of establishing a new genus for this real *Orbitolites*.

is a relatively irregular one. Thus the arrangement like an engine turned pattern (such as is generally met with at the dorsal side of a watch), which is so characteristic for forma A_2, is absent, and the annular arrangement dominates.

Forma A_2. This form is the most common one. It shows a megalosphere of about 230 μ diameter (chamberwall provided with small furrows), followed by a spacious neck, which begins directly with a diameter of about the same size as the embryonic chamber and preserves this diameter till the end of it; this is not the case in the neck of A_1, which grows broader successively. This embryonic apparatus is succeeded by a very small number of chambers, divided into chamberlets, showing the peneropline type, while these chambers (4 or 5) are followed by annular ones. As the chambers always show two foramina in their marginal walls and each foramen opens into a chamberlet of the following row, the arrangement of the chamberlets is a very regular one and may be best described as showing an engine turned pattern. Apertures in a single row at the margin of the shell. Youngs of this form have been figured by RHUMBLER (Zool. Jahrb., vol. 24, 1906, Pl. 4, fig. 42*).

Forma B. This form begins with a chamber of about 25 μ diameter. It is followed by an irregular mass of chambers, showing scarcely the typical spiral arrangement found in *Peneroplis*. Yet there exists a very fine spiral but the thickness of the walls is the cause of its irregular shape. The developed shell shows that the chambers soon attain the annular shape. The chamberlets of later rows are smaller than those of megalospheric shells. The chamberlets of the inner annules show the arrangement of foramina, which is characteristic for *Sorites* according to DOUVILLÉ. But in the last formed rows the foramina are of the orbitolite type. Diameter of Forma A_1 and Forma A_2 up to 4 mm., that of Forma B up to 6 mm.

RHUMBLER has described lacineate forms of his *O. duplex* (= our *O. marginalis*) I will prove that this lacineation is also found in *Marginopora* in microspheric forms. RHUMBLER has found them in his "*O. duplex*" in the micro- as well as the megalospheric forms. They have something to do with the forming of plasmodiospores and consequently are only to be found in the forms A_1 and B.

In his description RHUMBLER (1906) mentions and figures the forming of plasmodiospores in both forms, so that *Orbitolites marginalis* shows the typical trimorphism and typical heterogamy.

I must especially call the attention to the finer structure of the outer walls, which are very thin; AWERINZEW mentions real pores in the chamberwalls of the first chamber of his *O. complanata* (= *O. marginalis*). LISTER [1]) and RHUMBLER (1906) both mention fine pores in

1) LISTER, l. c. 1903, p. 102, fig. 34.

the wall of the embryonic chamber in "*O. marginalis*", while they are represented by fine furrows in "*O. duplex*". RHUMBLER says (p. 55): "Die Wand der megalosphärischen Embryonalkammer trägt häufig ein zierliches Relief von zahlreichen Grübchen, die z. T. deutlich in Längsreihen angeordnet sind, zu einer echten Perforierung der Embryonalkammerwand, wie sie bei *Peneroplis, Orbiculina* und, wie ich mich im Einklang mit LISTER überzeugt habe, auch bei *Orbitolites marginalis* Lam., angetroffen wird, kommt es hier aber nicht".

This view must be changed in some points:

AWERINZEW has looked very sharply and his conclusion is quite right: the megalospheric form with small proloculum shows in all species of *Orbitolites* the fine pores of *Peneroplis*. These pores are also found in megalospheric *Praesorites orbitolitoides* n. sp.; RHUMBLER must have examined this Peneroplide, thinking he dealed with *O. marginalis*. But, as I mentioned already, *Praesorites orbitolitoides* is distinguishable from real *Orbitolites* only by the fact, that all three forms show the peneropline, spiroline type; there are, however, other characteristics, which I have already described, when dealing with this species [1]).

It is here the place to give attention to the genus *Sorites* Ehrenberg. As this genus, with a wide fossil distribution, must also be present in recent seas, according to CUSHMAN (The Foraminifera, 1928, p. 221), it is possible, if not certain, that we have to do in reality with *O. marginalis*, and especially with the Formae A_1 and B. For if we consider CUSHMAN's definition:

"Test discoid, planispiral in the early stages at least of the microspheric form, later annular, completely divided into chamberlets; typically in a single layer, those of each annular chamber communicating with the adjacent ones as with those of the preceding and succeeding annular chambers; wall imperforate except in the very earliest chambers; apertures in a single line along the periphery", we may observe, that the only difference between this description and that of real *Orbitolites marginalis* is formed by the communication of the annular chamberlets with the adjacent ones. But, when examining figures of *Sorites* we see that this communication is due to the fact, that two foramina of adjacent chamberlets fuse before reaching the chamberlets of the succeeding row. This can easily be observed in the inner annules of Formae A_1 and B of *Orbitolites marginalis*. Yet there is some possibility, that the form, mentioned f. i. by RHUMBLER as *O. duplex*, from the Mediterranean and Red Seas, may show other characteristics than the shape of the passages, if studied internally, which may lead to place it within the genus *Sorites* or rather *Amphisorus*.

2. *Orbitolites duplex* Carpenter. Pl. LVII, figs. 5, 7; Pl. LX; Pl. LXI, fig. 6; Pl. LXII, fig. 10.

For references to literature one may consult CUSHMAN, U. S. Nat. Mus., Bulletin 100, vol. 4, 1921, p. 485.

The literature on this species is very confused, as the external structure of fullgrown specimens is like that of *O. complanata*.

Only the internal structure, the shape of the chambers, especially on transverse section, gives a distinct difference between *O. duplex* (mihi) and *O. complanata*.

1) It is very probable that RHUMBLER studied only forms with large proloculum, so that the typical pores, occurring in Forma A_1, were not observed by him. So he concluded, that in his "*O. duplex*" the proloculum lacked pores, while in "*O. marginalis*" they were found up.

Three forms have doubtless been distinguished and they have been found together, without any other species of the genus *Orbitolites*, in large quantities at a single station: stat. 64.

The species was observed at following stations:

Stat. 64. Kambaragi-bay, Tanah Djampeah; up to 32 m.; very abundant, 4 microspheric specimens.
Stat. 66. Bank between the islands Bahuluwang and Tambolungan, South of Saleyer; 8—10 m.; 6 specimens, 1 microspheric.
Stat. 95. 5°43′.5 N., 119°40′ E.; 522 m.; 7 specimens, 1 microspheric.
Stat. 99. 6°7′.5 N., 120°26′ E., Anchorage off North Ubian; 16—23 m.; 1 specimen.
Stat. 133. Anchorage off Lirung, Salibabu-island; up to 36 m.; 3 specimens.
Stat. 169. Anchorage off Atjatuning, West coast of New Guinea; 57 m.; 1 specimen.
Stat. 252. West side of Taam-island; 9—36 m.; 1 specimen.
Stat. 258. Tual anchorage, Kei-islands; 22 m.; 5 specimens.

In this flat, often large form the originally simple row of chambers (on transverse section) shows the tendency to elongate in the direction transverse to the plane of the shell. But in the median plane all chamberlets are simple, and regularly arranged, so that a horizontal section shows the same architectonics as those which are found in *O. marginalis*. In the forms A_2 and B, however, in older shells the later formed annules of chambers show a median layer, accompanied on either side of the shell by a layer of superficial chamberlets. The canadabalsam-method solves at once the question, how this layer has been formed. As the form, called A_1, shows mostly a single foramen between the chambers of two following rows, when seen in transverse section, and only very old individuals show two of them (*duplex*-form), those specimens belonging to A_2 and B possess, when growing older, more than two foramina in transverse section. But as those foramina are always penetrating the walls vertically to the outer surface of that wall, and as this marginal wall shows rounded angles, it is obvious, that the outer foramina, viz. those, situated nearest to the flat sides of the shell, must be directed obliquely to the plane of the shell (and to the axis of the transverse section). So these two foramina of each chamber end at a somewhat shorter distance from the centre of the shell than the other ones. RHUMBLER has pointed out already in his description of the Foraminifera of the Plankton-Expedition, that the forming of new chambers depends partially on the situation and shape of the foramina, the protoplasm is streaming out. So we can imagine that the forces which make the protoplasm stream out from the central pores of a chamber are others than those, working on the protoplasm which streams out from the lateral ones. As the central pores are directed perpendicularly to the surface the protoplasm streaming out of them may easily fuse together and form a single chamber; this is not the case with the lateral masses of protoplasm, forming a haptogenous membrane before fusion with the central part can be possible. In this way two lateral superficial chamberlets are formed, but yet a foramen gives passage from it to the central chamber.

Description of the three forms:

Forma A_1. First chamber nearly globular, diameter $\pm$ 90 μ. Wall of this chamber very thick, of a brown colour, with fine, but true perforations. Neck of this chamber beginning narrow, ending with a diameter, which is somewhat, but only a little, larger. Wall of this neck showing fine furrows, but no pores. Following chamber ovoid, with

three foramina, giving rise to a third chamber, divided into three chamberlets. Then follows a fan-shaped shell, quite as in *O. marginalis* (mihi) and in *Peneroplis*, but the chambers become annular more soon. In transmitted light all chambers are visible, even those of the last formed annules. All chambers are simple in transverse section and of a very peculiar form, with a wide part in the centre and growing broader towards the ends. They possess three foramina each: one to the next chamber of the following row and two to the next chambers of the same row. Only those chambers of annular rings near the margin of well-developed old specimens show two foramina to the next chamber of the following row. Diameter of the whole shell up to 11 mm.

Forma A_2. First chamber never globular, generally ovoid, followed by a short, wide neck. A second chamber, not divided into chamberlets, but possessing a row of foramina (up to 20) encloses nearly totally the first chamber and its neck. Diameter of this embryonic apparatus, which must be considered as the complete embryon (HERON-ALLEN observed in some cases that even the next formed chambers are embryonic ones. See f.i. Phil. Transactions Roy. Soc. London, series B, vol. 206, Pl. 15, fig. 18) up to 1125 μ. The embryonic apparatus is followed directly by an annular arrangement of chambers. The older rings are not lucid in transmitted light, as the superficial layer of chamberlets prevents it.

The transverse section shows us, that the shape of the first chambers is similar to that of those, found in the external rings of Forma A_1. They have no superficial chambers, but show already the tendency to form them, as their superficial ends are broadened. At the fourth or fifth ring however superficial chamberlets are found, being built in the way we described above. Chambers high, with 3—6 large foramina opening into the next chamber of the following row and two foramina at each side to the preceding and following superficial chamber, in transverse section. Diameter of the whole shell up to 10 mm.

Forma B. Large, flat shells with a diamter up to 24 mm., thickness increasing to the periphery, marginal apertures numerous, in irregular rows of about 15 foramina. First chamber $\pm$ 20 μ, followed by a short spiral of only three evolutions, succeeded by a short fan-shaped part of the shell, in which the chambers are divided into chamberlets; then the annular chambers are formed. I have examined only 4 specimens; no traces of broodchambers or plasmodiospores have been found. A transvere section gives a clear idea of the structure of the chambers. They are not different from those, described in

Forma A_2, except for the first formed rings. These rings show the typical form of the chambers of Forma A_1, gradually increasing in height and then superficial layers of chamberlets are formed. The chambers continue to increase in height, so that even ten or more pores are necessary to let the protoplasm stream into the next chamber. The superficial chambers show the habitus, already mentioned.

V. Genus **Marginopora**.

This genus shows some peculiar features, somewhat different from real *Orbitolites*. Yet one may doubt if these differences are large enough to erect quite a new genus only for these characteristics. As it is, however, very probable, that some fossil forms, which show some more differences with *Orbitolites*, are closely allied to *Marginopora vertebralis*, the only known recent form, the existence of this genus may be useful.

CUSHMAN (The Foraminifera, 1928, p. 222) describes the genus as follows:

"(Genoholotype, *Marginopora vertebralis* Quoy et Gaimard)".

"*Marginopora* Quoy et Gaimard, Voyage de l'Astrolabe, 1833, fide BLAINVILLE, Actin. 1834, p. 412".

"*Orbitolites* (part) of authors (not LAMARCK)" [1]).

"Test in the early stages similar to *Sorites*, with one or two rows of apertures, later with the two original planes of chambers forced apart and filled with a high series of chamberlets, those adjacent in each annular chamber connecting, the outer wall projecting beyond the peripheral plane of the lateral chambers, the apertures in more or less vertical rows on the periphery with a horizontal row above and below".

"Recent. Indo-Pacific".

I have studied for the second time my material of *Omphalocyclus macroporus* [called *Sporadotrema errantium* in my article cited below [2])], and came to the conclusion that this *Omphalocyclus* shows very much resemblance in general with *Marginopora*.

I agree with DOUVILLÉ, when he says [3]): "On voit d'après cela que l'analogie signalée avec la structure des Orbitolites du type complexe, ne se poursuit pas dans le détail, la couche moyenne présentant dans son développement final une disposition très differente".

I suggest that especially the development of this central layer is such a very peculiar characteristic, that this is the principal reason for me to separate this genus from real *Orbitolites*. Yet I cannot go as far as WAYLAND VAUGHAN, who placed *Omphalocyclus* in the neighbourhood of *Orbitoides*, though it is very probable, that *Marginopora* derives from forefathers, which are closely allied to the TINOPORIDAE. This question will be discussed, however, at the end of this chapter.

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1) For recent literature one may also consult: I. M. VAN DER VLERK, Foraminiferen uit het Tertiair van Java (Wetensch. Mededeelingen, Dienst van den Mijnbouw in Nederlandsch-Indië, n° 1, 1924, p. 11).

2) HOFKER, J., Die Foraminiferen aus dem Senon Limburgens, IV, *Sporadotrema errantium* nov. spec. (Natuurhist. Maandbl. Limburg, vol. 15, n° 6, 1926, pp. 62—65.

3) DOUVILLÉ, H., Révision des Orbitoides (Bull. Soc. Géol. de France, ser. 4, vol. XX, 1921, p. 232).

The study of the *Omphalocyclus*-material (from the type-station, Maastricht), I possessed, gave me insight into the structure of the embryonic apparatus of the megalospheric form. I studied especially some canadabalsam-preparations and found, that the perforations, mentioned in my previous paper on this matter, are in reality the passages (foramina) leading to the surrounding chambers. The first chambers of megalospheric generations must be considered to be imperforate, though the state of fossilisation may be the cause of a kind of perforation.

The microspheric specimens however show a very high development of rough pores, which are very typical, especially for recent and fossil ANOMALINIDAE. So it is possible, as the microspheric form possesses always more primitive characteristics, that *Omphalocyclus* is very closely allied to the ANOMALINIDAE. I have suggested in my paper on this form, that it would be allied to the genus *Sporadotrema* and pointed out, when dealing with *Carpenteria* (see this part, p. 123) that *Sporadotrema* would be closely allied to *Carpenteria*, which is a real anomalinid species. It is a very remarkable fact, that the microspheric part of *Omphalocyclus* (*Sporadotrema errantium* mihi !) shows peculiar features of *Planorbulina*, belonging to the tinoporid tribe, but shows no similarities at all with the microspheric as well as the megalospheric forms of any species, allied to *Peneroplis* (PENEROPLIDAE). In this microspheric apparatus there is no trace of the fullgrown peneropline spiral of chambers, which is always present in all genera of real PENEROPLIDAE: *Peneroplis*, *Praesorites*, *Orbitolites*, *Alveolina* and *Alveolinella*. The spiral is very diffuse and chambers like those of *Planorbulina* are nearly directly developed.

When we bear these facts in mind "*Marginopora vertebralis*" or "*Orbitolites complanata* (part)" of authors must be closely allied to "*Omphalocyclus macroporus*" from the upper senonian beds of Maastricht.

So I am now inclined to believe, that my *Sporadotrema errantium* (*Omphalocyclus macroporus*) and *Marginopora vertebralis* (*Orbitolites complanata*) belong to the same genus [1]). As *Marginopora* is the older name, this genus must be called *Marginopora* Quoy et Gaymard (1834) in the case, that *Orbitolites complanata* from the Paris Eocene is not allied to this *Marginopora vertebralis*. (However, I must point out here, that CARPENTER in his large monograph on the genus *Orbitolites* [2]) mentions, that "he found that between the recent *Marginopora vertebralis* of QUOY and GAIMARD, and the fossil *Orbitolites complanata* of LAMARCK, the differences are so trivial as to amount at most to a specific distinction; so that the later genus must be abolished, and the australian disk ranked as the recent type of the fossil so abundant in the "Calcaire Grossier". So it is obvious that CARPENTER has dealt with *Marginopora vertebralis*, when describing his species *Orbitolites complanata*).

Description of the genus *Marginopora*.

Large Foraminifera forming a round, free living disc. Microspheric forms showing at the centre a somewhat irregular, very short spiral. Later coils of chambers annular, chambers triangular, as in *Planorbulina*; later coils with highly developed secondary chambers (lateral chambers), while the

1) I have to mention the remarkable fact, that recent *Sporadotrema* (Hickson) shows a thickening of the earlier chamberwalls by pseudochitinous layers, so that here also the pores of these chambers are completely closed in older species (see my Siboga-Report, Monograph IV, part. I, p. 23).

2) CARPENTER, W. B., Report on the specimens of the genus *Orbitolites* (Challenger-Reports, Zoology, vol. VII, 1883, p. 4).

median layer of chambers is reduced to a system merely of large passages. Microspheric forms with a highly developed margin, so that in some species the shell becomes plicate. In the marginal rows of chambers megalospheric brood is to be formed. In fossil forms a coarse perforation of the walls of the lateral chambers is met with.

All megalospheric generations begin with a more or less large chamber, which is never perforated. It is followed by two other chambers, not always situated in the plane of the shell, but always larger than the first chamber. Apertures in more or less vertical rows on the periphery with a horizontal row above and below.

Cretaceous to recent.

1. *Marginopora vertebralis* Quoy et Gaimard. Pl. LVII, figs. 1, 2; Pl. LXI, figs. 4, 5, 11; Pl. LXII, figs. 1—9, 11, 12.

Marginopora vertebralis Quoy et Gaimard, Voyage de l'Astrolabe, 1833, fide BLAINVILLE, Man. Actin., 1834, p. 412.

See for synonyms the critical review of the group *Orbitolites*. The species has been considered by most authors as belonging to *Orbitolites complanata*. As, however, the internal structure differs from that of real *Orbitolites*, and, as we have pointed out already that the genus *Orbitolites* is only to be differentiated into *O. marginalis* and *O. duplex*, the megalospheric form of which is identical with most forms called by earlier authors *O. complanata*, the latter must be dropped as a recent one.

Whether *Orbitolites complanata* from the Paris Basin Eocene is a distinguishable species or not, I cannot discuss here.

Marginopora vertebralis has never been described exactly by the different authors. It shows very typical characteristics, especially in the megalospheric forms, which could be expected as the microspheric form is the most conservative one. This microspheric form has been described as variety *plicata* and *lacineata*.

We will show, that *Marginopora* in megalospheric specimens always produces at their centre a calcareous deposit on the surface, as has already been mentioned by LISTER (Trans. Roy. Soc. London, vol. 186, p. 434). It is very remarkable, that the forms described by LISTER were found by Dr. HICKSON near Celebes (see for coincidence station 96).

The species has been met with at the following stations:

Stat. 60. Haingsisi, Samau Island, Timor; 23 m.; 1 microspheric specimen.
Stat. 96. South-east side of Pearl-bank, Sulu-Archipelago; 15 m.; abundant, megalospheric specimens.
Stat. 109. Anchorage off Pulu Tongkil, Sulu-Archipelago; 13 m.; 2 megalospheric specimens.
Stat. 169. Anchorage off Atjatuning, West-coast of New-Guinea; 57 m.; 1 specimen.
Stat. 172. Gisser; anchorage between this island and Ceram-Laut; 18 m.; 4 megalospheric, 1 microspheric specimen.
Stat. 193. Sanana-bay, East coast of Sula Besi; 22 m.; 7 microspheric specimens.
Stat. 220. Anchorage off Pasir Pandjang, West coast of Binongka; 278 m.; 10 megalospheric, but small specimens.
Stat. 252. West side of Taam-island; 9—36 m.; 11 megalospheric specimens.

There exists a very typical difference between the megalospheric forms of this species and those of *Orbitolites*, already described: the high development of the superficial chamberlets, at the cost of the median layer of chambers. The last mentioned chambers are very narrow and are composed more by their foramina than by their body. But the superficial chamberlets on the contrary are well-developed tubes, truncate at the superficial ends.

The two megalospheric generations are easily distinguishable by means of the structure of their margin, as I will show. This structural difference is due to the state of development of the median layer of chamberlets; in case they are very reduced, only few rows of apertures are seen on the margin, surrounded by two rows of furrows, the outlines of the tubular chambers; in case they are broader, a larger series of wide apertures (arranged in 5 or 6 rows) is visible, and the furrows are not so prominent. We will now begin with the description of the three forms,

Forma A_1. First chamber with a diameter of 140 μ, followed by a kidney-shaped second one, which seems to be nothing else than the neck of the first chamber, but very well developed. It is however very probable, that this neck-shaped chamber must be homologous with the second chamber of the TINOPORIDAE. It has nothing to do with the neck-chamber of the MILIOLIDAE or PENEROPLIDAE. This neck may be followed by a third chamber, not very large, and then the annular rings of chambers begin. They are triangular with a rounded external wall. This is the form of all median chambers. But very soon they are completely covered by the superficial ones. The whole centre of the shell is covered with an irregular layer of an amorphous chalkmass, so that slides only can give a clear idea of the central chambers. The whole embryonic apparatus measures about 400 μ. The surface of the shell, except the central part, shows rings of rectangular chamberlets, as the superficial ones are situated closely together. No trace of the typical lozenge structure is found here. The marginal face of the shell shows about three rows of pores, flanked by two rows of furrows, as I have described already. The shells measure $\pm$ 8 mm and are thin, the thickness at the margin being 400 μ. The margin itself is somewhat rounded. A transverse section, treated with canadabalsam and acidum hydrochloricum, shows us that the median layer of chamberlets in the centre is shaped similar to those, found in megalospheric forms of *Orbitolites duplex* (mihi!), but the inner layer of chambers is only a network of canals in later rings. Tubular superficial chamberlets branch off from these canals, the chamberlets of one side alternating with those at the other side. They are directed towards the centre, so that a peculiar structure is formed. (As I have mentioned already in the description of the whole genus, this direction of the lateral chambers is quite the same in "*Omphalocyclus macroporus*", so that transverse sections of that genus and

of *Marginopora* are nearly identical). The external walls of these chamberlets are very thin. Only the median "canals" open at the margin into apertures.

Forma A_2. This generation shows a much larger embryonic apparatus, very similar to that, described in Forma A_2 of *Orbitolites duplex* (mihi). Diameter of complete apparatus 600—800 μ.

The shell is much thicker, than that of A_1, and the margin is not rounded, but straight. This margin shows a highly developed perforation, the furrows of the superficial chambers are scarcely to be seen. The superficial tubes are not so long, so that much space is left between the two rows of tubes (in transverse section) to the "canals". This is the reason why the apertures are so numerous. The central chamberlets are of a primitive shape, but the shell becomes more complicated towards the periphery. Diameter of whole shell up to 12 mm.

Forma B. This is the lacineate (or plicate) variety, mentioned above. The "variety" *lacineata* has been described for the first time by BRADY (Quart. Journ. Micr. Soc., vol. 21, 1881, p. 47) and that called *plicata* by DANA (J. D. DANA, C. WILKES. U. S. Exploring Exped., vo. 7, Zoophytes, p. 706, Pl. 60, fig. 9). HERON-ALLEN and EARLAND have already suggested, that these two forms are identical (Foraminifera of the Kerimba Archipelago, Part. II, Trans. Zool. Soc. of London, vol. XX, 1915, p. 60*b*).

Central part of the shell beginning with a somewhat spiroline arrangement of simple chambers, translucid. Later chambers very complicated, similar to those of the microspheric form of *O. duplex*, but the chamberlets are often divided once more into chamberlets of second degree. In this way a very complicate structure is formed. The external rows of chambers are built as brood-holes, as has been described already by LISTER; but in the Siboga-material I could not find embryons in them.

Some short remarks must follow here on LISTER's observations on this genus. On Plate IX of his work, cited above, he has figured the plasmodiospores of this species. We will measure them: those, figured on fig. 44 are formed in the microspheric lacineate form, and have an average diameter of 350 μ; those, found in megalospheric parents, however, have a diameter of 500 μ. So we have here a clear example of trimorphism and we see that Forma A_1 is the generation, which can be derived from a microspheric parent, while Forma A_2 can be derived from a megalospheric one.

This statement may be of some systematical value, as in the real PENEROPLIDAE things are just reversed: the form with small embryonic apparatus derives from a megalospheric parent, that with larger proloculum from a microspheric one. So we find once more that *Marginopora* is not a peneropline form at all.

Short critical review of the literature on *Orbitolites* and on *Marginopora*:

(I will only mention the literature, in which good figures have made it possible to recognise the real features of the shell).

CARPENTER, W. B., Challenger Report, Zoology, vol. 7, 1883, Genus *Orbitolites*, Pl. III, figs. 1 and 2: *O. marginalis*; fig. 8: *O. duplex*; Pl. IV, fig, 1: *O. marginalis*, Forma A_2, figs. 2, 4, 5: *O. duplex*, Forma A_1, fig. 6: *O. duplex*, A_2, figs. 9 and 10: *O. duplex*, A_2; Pl. V, figs. 1—10: *O. duplex*, figs. 11—18: *Marginopora vertebralis*, fig. 18: Forma A_2; Pl. VI, figs. 1 and 3: *Marginopora*, Forma A_2, fig. 2: *O. duplex*, Forma A_2, fig. 5: *Marginopora*, A_1, fig. 6: *O. duplex*, A_1, fig. 7: *Marginopora*, fig. 8: *O. duplex*, A_2, fig. 9: *Marginopora*; Pl. VII, *Marginopora*.

CARPENTER, W. B., PARKER, W. K., JONES, T. R. An introduction to the study of the Foraminifera; 1862. Pl. IX, figs. 1 and 2: *O. marginalis*, Forma A_2; Pl. IX, figs. 7 and 8: *O. duplex*, Forma A_2 or A_1.

MÖBIUS, K., Beiträge zur Meeresfauna der Insel Mauritius und der Seychellen, 1880. Pl. IV and V: *O. duplex*, Forma A_2 and A_1.

BRADY, H. B., Report Voyage Challenger, Zoology, vol. 9, 1884. Pl. XV, figs. 1—5: mostly *Peneroplis orbitolitoides*; Pl. XVI, figs. 1—4, 8—11: *O. complanata*; Pl. XVI, figs. 5, 6, 7: *O. duplex*; Pl. XVII, figs. 1—6: *O. duplex*.

HERON-ALLEN, E. and EARLAND, A. The Foraminifera of the Kerimba-Archipelago, Trans. Zool. Soc. London, vol. XX, Part II, 1915. pp. 604—605: *O. marginalis* and *O. duplex* are only forms of *O. marginalis*; p. 606: *O. complanata* (microspheric flat, not laciniate) must be *O. duplex*. *Marginopora* has not been observed.

CUSHMAN, J. A., A monograph of the Foraminifera of the north pacific Ocean, Part VI, MILIOLIDAE, U. S. Nat. Mus., Bull. 71, 1917. I have already critisised the beautiful and sharp defined descriptions, pp. 92—97. The same thing can be said of CUSHMAN, Foram. Philippine and adjacent seas, U. S. Nat. Mus., Bull. 100, 1921.

LISTER, J. J., Foraminifera, in: A treatise on Zoology, by RAY LANKESTER, Part. I, 1903, p. 100—107. Fig. 33: this is really *O. marginalis*; Fig. 35, A—A'': *O. duplex*, Forma A_2, B: Forma B, but of *O. marginalis*. Fig. 36, A: *O. complanata*, Forma A_1; B: *O. duplex*, Forma B. Fig. 37, A: *O. complanata*; B: *O. duplex*, Forma B.

RHUMBLER, L., Die Doppelschalen von *Orbitolites*, Arch. für Protistenkunde, vol. 1, 1902. All specimens, which are described, are *O. marginalis*.

—— Foraminiferen von Laysan und den Chatham Inseln, Zool. Jahrb., vol. 24, 1906. Pl. IV: All specimens are *O. marginalis*.

FLINT, J., Recent Foraminifera, Rep. U. S. Nat. Mus., 1899. Pl. 50, fig. 2: *O. marginalis*? Pl. 51, fig. 1: *Peneroplis orbitolitoides*; Pl. 51, fig. 2: *O. marginalis*; Pl. 51, fig. 3: *O. marginalis*.

VI. Genus **Alveolinella.**

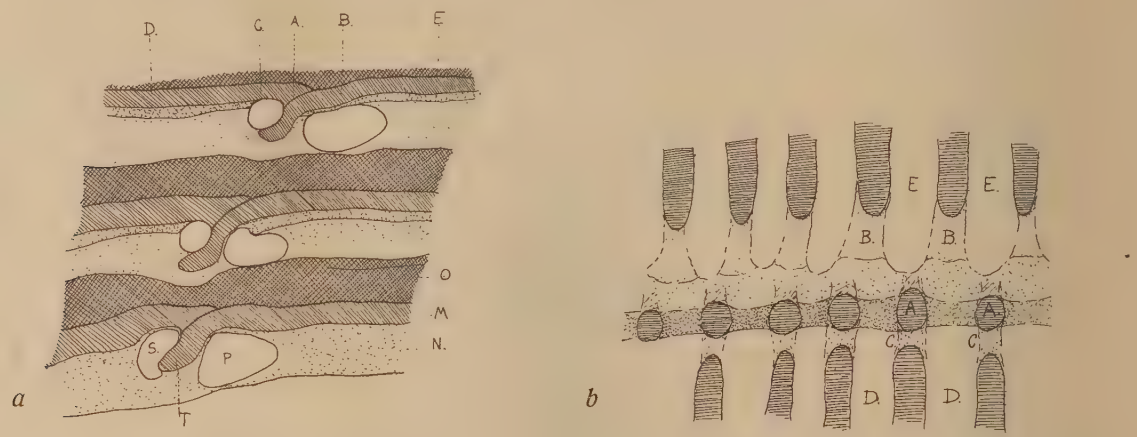
The genus has been erected by H. DOUVILLÉ [1]) in the year 1906:

"*Alveolinella* n. gen.: se distingue d'*Alveolina* parceque les cloisons présentent plusieurs rangées d'ouvertures. C'est là un caractère important et qui n'a pas été rencontré jusqu'ici avant l'époque actuelle; il nous paraît motiver l'établissement d'un genre nouveau, dont le type sera *Alv. Quoyi* (bien figuré par CARPENTER dans son Introduction à l'étude des Foraminifères, Pl. VIII). L'endosquelette est aussi bien plus complexe: non seulement on distingue des cloisons transverses perforées d'une ou deux ouvertures dans le voisinage de la cloison, mais il existe encore d'autre cloisons secondaires plus ou moins complètes, parallèles à la lame spirale et qui viennent s'intercaler entre les rangées d'ouvertures des cloisons".

1) DOUVILLÉ, H., Les calcaires à fusulines de l'Indo-Chine, Bull. Soc. Géol. de France, ser. 4, vol. VI, p. 585.

This description, though short, is very exact; but are these differences important enough to base a new genus on them? Only a single species, belonging to this genus, has been described, the only living species with such a complex internal structure [1]). As we will describe below, this complexity can easily be brought in relation with the internal structure of the more primitive shells (f. i. *Alveolina* or *Borelis*). But, as the real texture of these primitive forms has not been cleared up as much, as one could wish, and as I did not possess material of all these genera to study them, I do not know whether forms as *Flosculina* etc. are really allied to *Alveolinella* or not [2]). It is possible that *Alveolinella* is closely allied to *Peneroplis*, and this fact lead to the circumstance, that I placed the species *A. Quoyi* in the family of the PENEROPLIDAE. Yet there are some remarkable differences.

CUSHMAN [3]) describes the family of the ALVEOLINELLIDAE as follows: "Test imperforate except the proloculum and second chamber; general shape of the test fusiform, coiled about an



Textfigure 32. *Alveolina*. Schematical sections through fossil *Alveolina* from the basin of Paris. The letters A, B, C, D and E indicate places of equal arrangement in the two figures *a* and *b*.
a: part of a transverse section; *b*: part of a tangential longitudinal section; × 250.
O.: ventral wall of the chamber. P.: real chamber. M.: dorsal wall of the chamber. N.: wall between two chamberlets.
S.: foraminal communication between two adjacent chamberlets. T.: lip of the foramen.

elongate axis; chambers completely involute, divided into chamberlets; apertures numerous, in one or more rows on the face of the last-formed chamber".

I must point out at once, that the initial chambers of my *Alveolinella*-material lack every trace of perforation in all three generations. We have shown, when dealing with *Orbitolites*, that some generations lack this perforation too, so that this characteristic is not a constant one even in those forms, which are doubtless PENEROPLIDAE. On the other hand, the megalosphere is of the typical peneropline type, rounded, with spiroline neck.

The finer structure of the walls is very like that of real *Peneroplis*: the walls between

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1) We have to mention the fact, that RUTTEN (Samml. Geol. Reichs-Mus. Leiden (1), IX, p. 219—224, 1913) described a fossil species, *Alveolinella bontangensis*, which must be considered as a link between *Alveolina* and recent *Alveolinella Quoyi*. (See I. M van der Vlerk, Studiën over Nummulinidae en Alveolinidae, Verhandl. Geol. Mijnbouwkundig Genootschap voor Nederl. en Koloniën, Geol. Serie, vol. V, p. 395).

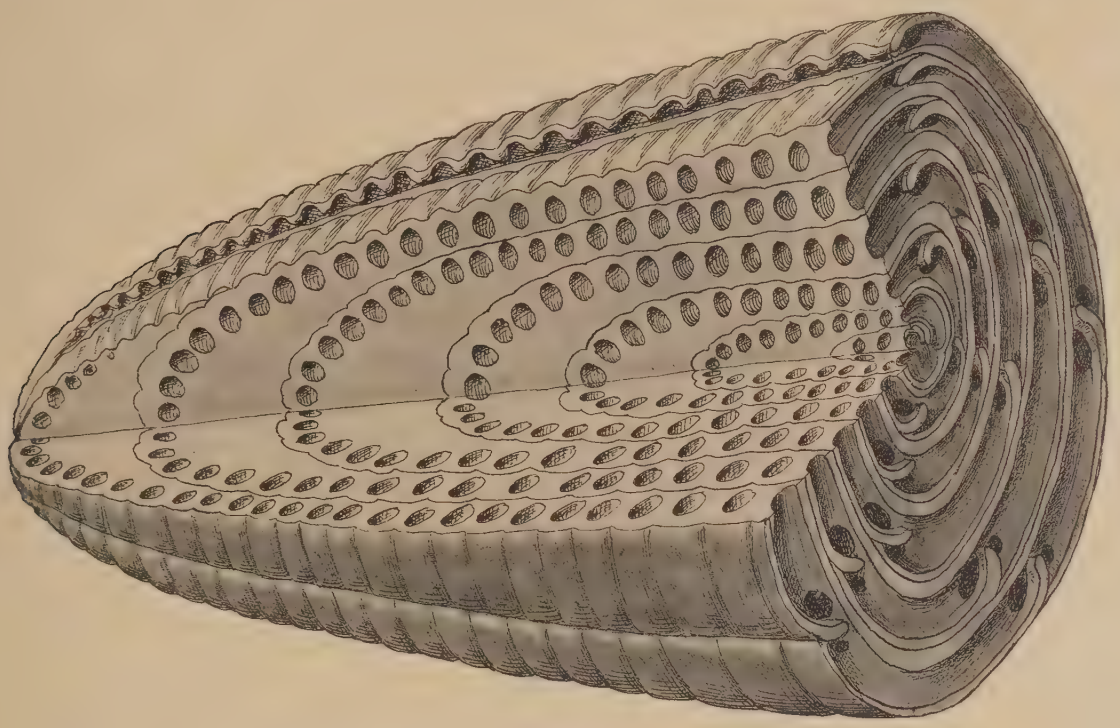
2) RUTTEN (Nova Guinea, Vol. VI, Géologie, Livr. 2, 1914, p. 44) pointed out, that it would be better to drop the genus *Flosculinella* Schubert, as they "schon die Anfänge einer Entwicklung in die Richtung der rezenten Alveolinellen zeigen und deshalb mit diesen der *Alveolina* s. str. aus dem Eozän gegenüberstehen".

3) CUSHMAN, J. A., The Foraminifera, 1928, p. 224.

two chambers of succeeding rows are double; and even the complexity of the chambers is found in some degree in fullgrown specimens of *Orbitolites*.

I was able to study very fine material, from the Eocene of Paris, of *Alveolina boscii* Defrance (now known as *Borelis* or *Oryzaria* Defrance; see CUSHMAN, The Foraminifera, 1928, pp. 226—227).

CUSHMAN describes *Borelis* als follows: "Test globular or fusiform, coiled planispirally about an axis, early coils as well as later ones low; chambers divided into chamberlets; apertures usually in a single row". This description is very exact; I have to add only the following remarks:



Textfigure 33. Schematical figure of *Alveolina (Borelis) boscii*, showing transverse and longitudinal sections, × 65; from specimens from the Eocene of Paris.

1. The chambers are not totally divided into chamberlets, as the last formed part is not divided by the secondary walls, so that a communication between the chamberlets persists.

2. The communication between two succeeding chambers is formed by a row of narrow foramina, situated at the basal part of the frontwall of the first chamber. This frontwall is thin and looks on transverse section like an overhanging lip, protruding from the upper wall [1]). Each foramen is situated just before the ends of the secondary walls and shows a very peculiar shape, as it is formed like a **V**, seen from the dorsal wall [2]). So this shape is quite the same as that of the foramina found in some forms of *Peneroplis*, which I have already

1) CARPENTER, probably bearing in mind a section from *Lacazina*, figured in his "Introduction", p. 100, Fig. XXII, a section with two lips at the end of each chamber. I never saw any fossil *Alveolina* with those lips. It will be necessary to give attention to this fact, as even in recent handbooks (f. i. v. D. VLERK and UMBGROVE, Tertiaire Gidsforaminiferen, Wet. Med. v. d. Mijnbouw in Nederl. Indië, N° 6, 1927, Fig. 14) this wrong figure occurs again.

2) At least in typical fossil *Alveolina*.

mentioned. But, as the foramina are arranged closely together, the two ends of them, which are the most neighbouring, fuse together and in this way a communication is formed through the secondary walls of the chamberlets of the succeeding chamber. This is the reason why in transverse sections two openings in the secondary chamberwalls are found next to the chamberwalls, one before, and one, smaller, behind the chamberwall.

3. The fused ends of two neighbouring foramina run straight between two secondary chamberwalls to the following chamber. The "chamberlets" show on horizontal section a round diameter, so that they look much more like passages, than like real chamberlets. As in *Orbitolites* fused foramina are also a common phenomenon, I may be quite right when suggesting, that the "chamberlets" of the fossil *Alveolina* are but foramina, and that the chamber itself is formed by the part, in which no secondary chamberwalls are found. It is a fact, that the last formed chamber ends with the openings, forming the beginning of the chamberlets [1]).

We have now to discuss the nomenclature of the "genera", allied to the just described form. As we will show further on, the genus *Alveolinella* shows some peculiarities with respect to the fossil forms, the later chambers being much higher and having more than a single row of foramina, obviously due to the larger volume of the chambers.

RUTTEN has described a tertiary form with two rows of foramina, while recent *Alveolinella* shows three rows in the adult forms (*Alv. bontangensis*, cited above).

As I have stated, describing *Alveolinella*, the first coils of chambers often show the primitive characteristic of possessing only a single row of foramina. In some forms these chambers are followed by a few with two rows, and finally chambers with three rows of foramina are developed.

So the development of the foramina of *Alveolinella* is quite the same, as that which has been found in *Orbitolites duplex*.

I have also shown, that *O. marginalis* possesses a single or a double row of passages, *Praesorites* however only a single row in the adult.

It was a matter of view to separate *Praesorites* from *Orbitolites*, as not only the foramina, but also the development of the secondary chamberlets in *Praesorites* is different from that of *Orbitolites*. But must we separate *Orbitolites marginalis* and *O. duplex* as two different genera? There is no reason for it.

Then, is there any reason to separate *Borelis* (*Alveolina*) from *Alveolinella* as a different genus? I do not believe so.

I am sure, that a deeper study of the fossil species, will show us these relationships more clearly and that we will be obliged to drop a "genus" such as *Alveolinella*.

1. *Alveolinella Quoyi* (d'Orbigny).

Alveolinella Quoyi d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 306.

I will state that *A. Quoyi*, described by D'ORBIGNY, must be the microspheric form of

1) The same phenomenon can be stated in forms with partially formed chamberlets, such as *Praesorites*. Here also each chamber is formed *a*, by the partial chamberlets, *b*, by the chamber itself, and is closed by a wall, with foramina forming the beginning (often after fusion) of the partial chamberlets of the following chamber. So it is very probable that *Alveolina* and *Alveolinella* possess chambers, divided into partial chamberlets.

A. boscii d'Orbigny. I will also prove that the species *A. elongata* d'Orb. is nothing else than the third form of this trimorphic species. As CUSHMAN (The Foraminifera, 1928, p. 358) has proposed to give in such a case all three forms the name of the microspheric generation, we must call it *Alveolinella Quoyi*, the other names being synonyms. There is, however, another argument for this calling our species *Alveolinella Quoyi*.

Some authors must have described specimens of very small dimensions from other parts of the world, from Mauritius [1]) and the Hawaiian Islands [2]). All these authors mention the relative smallness of the specimens. Especially MÖBIUS has given an exhaustive description of this "*A. boscii*" from Mauritius. But as the reader may easily state, if looking at MÖBIUS' figures, the internal structure is very different from that, described by CARPENTER in his Introduction, dealing with recent *A. Quoyi*, gathered in australian and philippine seas [3]). MÖBIUS' figures of that small "variety" show the typical structure of a simple *Alveolina* s. s., described by DOUVILLÉ (l. c., 1906, p. 585) as follows: "*Alveolina* d'Orbigny, 1826: test calcaire, compact; fusiforme; cloisons droites, percées à la base d'une rangée d'ouvertures; cloisons transverses complètes..... On peut considérer comme type *Alv. boscii* du calcaire grossier".

I have examined specimens of this species "*A. boscii*" from Paris and I can state, that they show simple chamberlets, not divided into horizontal "storeys" as CARPENTER describes them and as I have found them in my material gathered by the "Siboga". Surely there exists no difference between this "*A. boscii*" from Paris and *A. boscii*, mentioned and fully described by MÖBIUS from the reefs of Mauritius (recent!). So it may be very probable that a species of *Alveolina* s. s. is still living now, but not in the australian and malayan region. This species must be "*Alveolina boscii* d'Orbigny" in respect with its simple structure. (As the species has been found in much samples together with *A. melo* — recently called *Borelis* — and this species shows nearly all the structural characteristics of "*A. boscii*", there is some probability that these two species are only different generations of the same one. Further investigations in this direction may clear up this question).

The other "variety" however, found in the Malayan Archipelago must be called *Alveolinella Quoyi* d'Orbigny to ovoid all further confusions.

Alveolinella Quoyi was found at the following Siboga-Stations:

Stat. 133. Anchorage off Liru'ng, Salibabu-island; up to 36 m.; 1 specimen.
Stat. 209. Anchorage off the south point of Kabaëna island; 22 m.; 3 specimens.
Stat. 240. Banda-anchorage; from 9—45 m.; abundant.
Stat. 258. Tual-anchorage, Kei-islands; 22 m.; abundant.
Stat. 301. 10° 38′ S., 123° 24′.2 E., Pepela-bay, East coast of Rotti-island, 27—45 m.; abundant.

I have used several methods to clear up the structure of this peculiar species. Some specimens were sectioned by grinding on an emery-stone. Other ones were examined by means of my canadabalsam-method, which gave very good results and others again were decalcified (they were preserved in alcohol) and sectioned with a microtome. In this way the protoplasm could be studied.

1) MÖBIUS, K., Foraminiferen von Mauritius (1880, p. 79, Pl. III, figs. 13—15, Pl. IV, fig. 1).
2) CUSHMAN, J. A., U. S. Nat. Mus. (Bull. 71, Pt. VI, 1917, p. 98, Pl. 39. fig. 3).
3) CARPENTER, Introduction to the Study etc., 1862, p. 99.

Forma A_1. Relatively large specimens, fusiform, length up to 7 mm., diameter up to 1,5 mm.; the shape is cigar-like. with pointed ends. The first chamber, of a diameter of about 45 μ, is followed by a very short neck. Traces of very fine pores could be observed. Then several whorls of narrow chambers follow in a closed spiral, very similar to the first coils of *Archaias*, succeeded by the typical whorls of chambers, increasing slowly in height. The storeys in the chamberlets are soon developed.

Forma A_2. Relatively large, robust fusiform specimens, length up to 9 mm., diameter up to 2 mm.. Ends of the shell truncated or rounded. First chamber very large, somewhat globular, diameter 130 μ, followed by a long neck, which surrounds this chamber nearly completely. Pores are not present, as I could state, not only in slides, but also in sections through a decalcified specimen. The neck-chamber is followed directly by the broad chambers, characteristic for the ALVEOLINIDAE. But these chambers are very low, the diameter of the shell increasing but slowly, even the first of these chambers shows no storeys, but the second one shows already the roof canal (which will be described further on). After five or six coils the height of the chambers increases suddenly.

Forma B. Large specimens, nearly cylindrical, often crooked. Length of the whole shell ± 15 mm., diameter 3 mm. First chamber 20 μ followed by a short spiral of minute chambers, in the beginning built as in *Peneroplis*, afterwards as in *Archaias*. The walls of these chambers are very thick. Then the typical chambers follow, increasing slowly in volume. In fullgrown specimens 10—12 whorls are formed. The long chambers, so peculiar to Forma A_2, and even to Forma A_1, in transverse section, are absent totally, the length of the chambers increasing slowly too.

We will now give the description of the fully outgrown chambers, as they are shown in longitudinal and transverse sections of the fusiform shell (longitudinal = parallel to the long axis of the shell), in canadabalsam-preparations. This structure of the chambers has already been described very accurately by CARPENTER in his Introduction.

The first chambers of the megalospheric form with small proloculum and those of the microspheric form are broad peneropline ones. But very soon they grow out in the direction of the axis of the later shell. This enlargement of the chambers is accompanied by division into chamberlets; these chamberlets however are not separated from each other by complete walls, as they communicate by means of a secondary foramen, which is situated near the base of the chamber. The chambers soon increase in size, in a direction vertical to the axis of the shell. In this case the secondary foramina are situated in the middle of the secondary walls, but always near the roof-wall of the chamber of the preceding row. In this way each chamber,

divided into chamberlets, looks, when decalcified after filling it up with canadabalsam, as if it were a column of vertebrae of some fish. But with the further development of the chambers their complexity becomes more typical. First the roof-canals appear. I have called these partitions of chamberlets canals with respect to their small diameter [1]). They form narrow passages along the roof of the chamberlet and are separated from the mean cavity of the chamber by a thick secondary wall. Above each chamber two roof-canals are running and I believe, that the ridges, seen at the wall of the shell from without, are nothing else, than these roof canals. At the end of each chamberlet they bend down to the aperture of the chamberlet, but they do not reach it; in this way, above the aperture of each chamberlet, two apertures of the roof-canals are situated (or a single one, as sometimes the two roof-canals fuse). In yet later whorls, the chambers become more complicated, as the cavity of them is divided into two, or even three parts, situated just above each other. Sections through the later whorls thus show a row of two or three rounded cavities above which are situated two narrow openings, the roof-canals, all arranged in a T-like figure. They represent the simple chamberlet of *Alveolina* s.s. (the series of cavities, found just beneath the roof-canals, show some irregularities, as in some chamberlets they are also double, in other ones however they are but simple). Especially in Forma A_2 (with larger proloculum) the ends at the points of the fusiform shell of each chamber show a large increasement of foramina, and, consequently of partial secondary chamberlets. Thus a very high chamber is formed. I suggest that this chamber with its large cavity must be regarded as a brood-chamber. This is the more evident, as the form with larger proloculum produces plasmodiospores in the PENEROPLIDAE. I am inclined to consider the cavities as fullgrown foramina. This conclusion must be the right one, as the walls of the cavities are very thick, as it is the case with the walls of the passages, described in *Peneroplis*, especially in the "varieties" known as *Dendritina* and *Spirolina*. The canals and cavities of the chambers of *Alveolinella* can easily be derived from the complicated foramina of *Peneroplis*. So we have here a fine example of a complex Foraminiferum, in which the foramina are of much more importance than the chambers themselves. This statement will prove to be of some interest, as in other groups (ANOMALINIDAE f.i.) the so called stolones are nothing but outgrown foramina, and as the umbilical system of ROTALIIDAE once more is formed by foramina.

Seen in this light, the complication of structure of *Alveolinella* vanishes, and we can say, that *Alveolinella* differs from *Alveolina* only by its very large development of foramina.

In some very highly developed specimens there may exist a second passage between two chamberlets of the same chamber. As the chambers in those specimens are relatively high, this passage is situated above the first mentioned one, on the place, where the roof-canals of the preceding chamberlet open into the cavity of the chamberlet itself.

I have found some specimens of the megalospheric type with large proloculum, which showed two embryonic apparates. As the only extern difference with normal specimens which could be observed, was the relative stoutness, these diploid individuals must be considered as univalent.

I have studied sections through decalcified specimens, in which the protoplasm was

1) They were already called "canals" by other authors too, see f.i. v. d. VLERK, l.c., 1922, p. 394.

preserved. The individuals were of Forma A_2. The proloculum partially filled up with protoplasm, showed no nuclear structure, nor could I observe a nucleus in the inner parts of the shell. Yet I am inclined to believe that in the proloculum a nucleus, though a diffuse one, was present, as the protoplasm here was more stainable than in other parts of the shell and more finely granulated. The protoplasm in the outer layers showed some particularities. It was highly stainable with haematoxylin and numerous bodies were found in it, each with a distinct nucleus. I was at first inclined to believe, that I had to do with zooxanthellae. But as in other Foraminifera these zooxanthellae were with difficulty to stain with haematoxylin, I believe, that we have here an example of sporulation of the animal itself. This agrees with the fact, that other individuals of the same form proved to be empty, or showed protoplasmic remains only.

PLATE XXXIX.

Life-history.

Fig. 1. Transverse section through an encystated individual of *Eponides repandus*, showing the thickness of the ventral wall of the cyst; × 300.
Fig. 2. Horizontal section through *Eponides repandus*, with large proloculum, and distinct chromidium; × 300.
Fig. 3. Section through *Eponides*, showing the beginning of forming of the spores, and vacuolisation of the protoplasm; × 550.
Figs. 4 and 5. Sections through *Eponides*, with cystwall; × 160.
Fig. 6. Young of A_1-form of *Miliolina circularis*, with two nuclei; × 300.
Fig. 7. Young of A_1-form of *Miliolina circularis*, with a single nucleus; × 300.
Fig. 8. Adult specimen of A_1-form of *Miliolina*, showing a multitude of nuclei in the central part of the protoplasm; × 300.
Fig. 9. Section through a microspheric form of *Miliolina*, with many nuclei; × 300.
Fig. 10. Transverse section through a cyst of *Miliolina*, showing 4 plasmodiospores; × 160.
Fig. 11. Optical section from a cyst of *Miliolina circularis*, showing the plasmodiospores and the parent shell; × 300.
Fig. 12. Transverse section through forma A_2 of *Miliolina circularis*, with nucleus and chromidium; × 300.
Fig. 13. Section through a cyst of *Miliolina*, with plasmodiospores, one of them with easily distinguishable nucleus; × 300.

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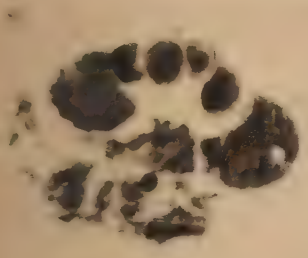

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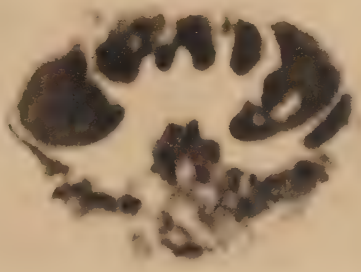

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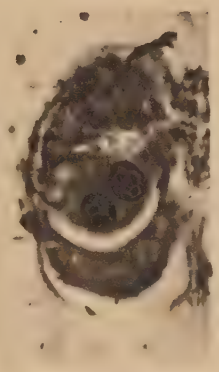

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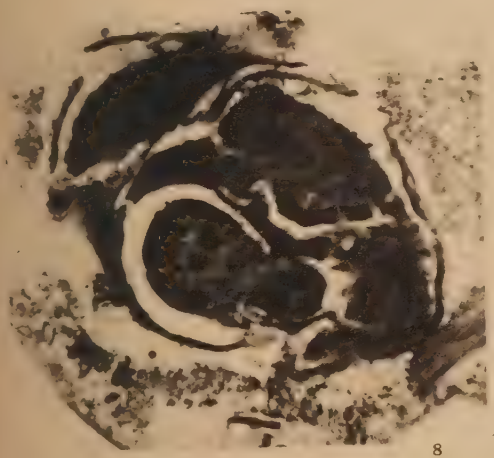

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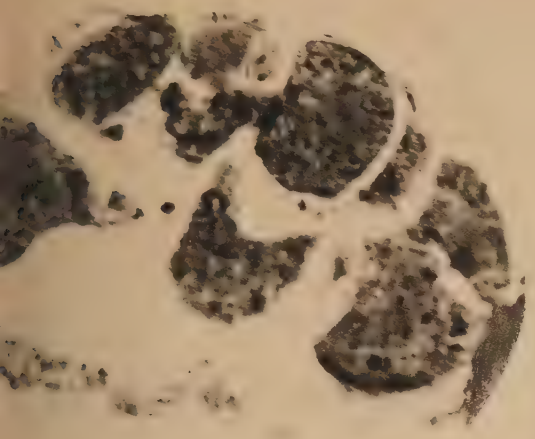
PLATE XL.

Life-cycle, Nodosinum, Placopsilina, Alveolina.

Fig. 1. Transverse section through *Eponides repandus*, decalcified and stained, showing chromidium; × 300.
Fig. 2. Longitudinal section through *Nodosinum gaussicum*, forma A_1; × 14.
Fig. 3. Transverse section through an encystated specimen of *Eponides repandus*, showing nucleus and umbilical canal plasma, reaching the ventral wall of cyst; × 160.
Fig. 4. Section through *Eponides repandus*, with microspores; × 550.
Fig. 5. Longitudinal section through a part of *Nodosinum gaussicum*; × 14.
Fig. 6. Longitudinal section through later chambers of *Nodosinum gaussicum*; showing "Zotheken"; × 14.
Fig. 7. Part of a section of fig. 6, much more enlarged, to show the structure of the wall near the aperture; × 100.
Fig. 8. Transverse section through an aperture with its "Zotheken"; × 80.
Fig. 9. *Placopsilina cenomana*, transverse section, canadabalsam-preparation, showing the pores; × 95.
Fig. 10. Transverse section through *Alveolina boscii* from the eocene of Paris; × 110.



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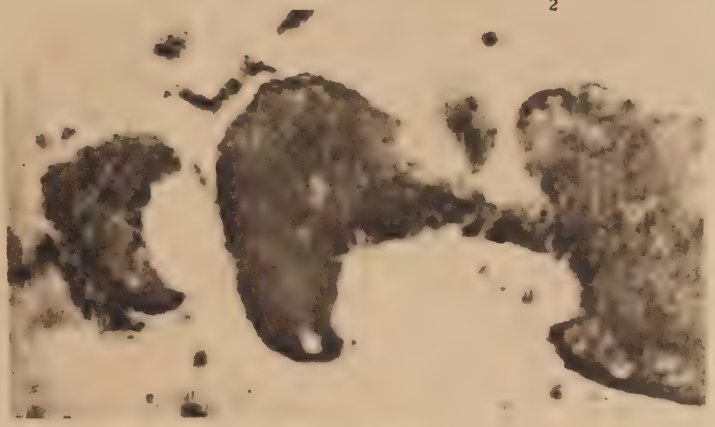

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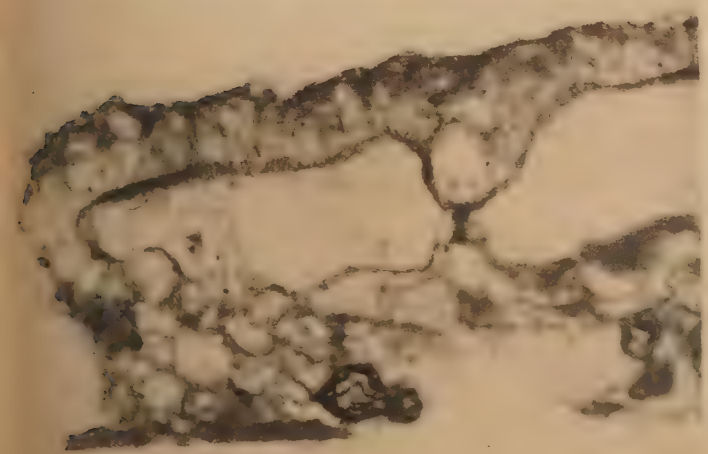

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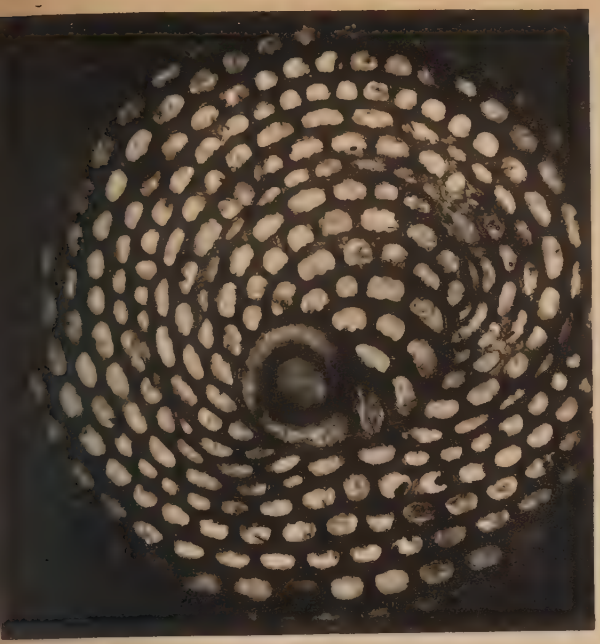
LIFE-CYCLE, NODOSINUM, PLACOPSILINA, ALVEOLINA.

PLATE XLI.

Orbitolites, Nummulites, Alveolinella.

Fig. 1. *Orbitolites marginalis*, forma A_2, showing the peneropline development of the centre of the shell; × 200.
Fig. 2. Forma A_1 of *Nummulites spec.*, horizontal section; × 200.
Fig. 3. Forma A_2 of *Nummulites spec.*, horizontal section; × 20.
Fig. 4. Fotograph of a glassplate, on which are attached all forms of *Nummulites spec.* together with the marl in which they were found. Natural size.
Fig. 5. Forma B_1 of *Nummulites spec.*, horizontal section; × 20.
Fig. 6. *Alveolinella Quoyi*, megalospheric specimens; × 5.
Fig. 7. *Alveolinella Quoyi*, above a microspheric, underneath some megalospheric specimens; × 4.
Fig. 8. *Alveolinella Quoyi*, tangential longitudinal section of a decalcified specimen, showing chamberlets, chambers and foraminal canals of different layers; × 60.



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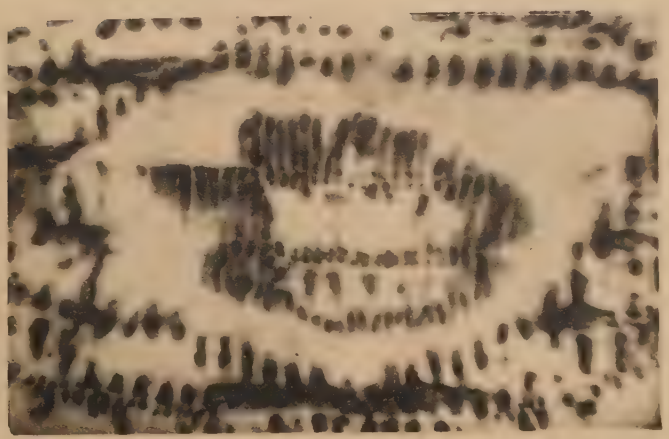

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ORBITOLITES, NUMMULITES, ALVEOLINELLA.

PLATE XLII.

Astrorhiza arenaria, Rhabdammina abyssorum.

Fig. 1. *Astrorhiza arenaria*, var. *agglutinans*; × 10.
Fig. 2. *Astrorhiza arenaria*, var. *agglutinans*, same specimen, other side of the test; × 10.
Fig. 3. Same specimen, section; × 10.
Fig. 4. Section of *Astrorhiza arenaria*; centre with two apertures, filled up with protoplasm, with nucleus. Wall with shells of other Foraminifera and sponge-spicules, especially in the inner layer; × 40.
Fig. 5. Reconstruction of *Rhabdammina abyssorum*; × 10.
Fig. 6. Part of the same, centre with base of a branch, showing the irregularly placed larger sand grains; × 40.
Fig. 7. Protoplasm of *Rhabdammina*, with food-particles; × 180.
Fig. 8. Slide through the wall of the central part of *Rhabdammina*, showing its structure; × 40.
Fig. 9. Slide through the central part of *Rhabdammina*; × 14.
Fig. 10. Slide through a forking branch of *Rhabdammina*; × 14.
Fig. 11. Slide through the wall of a forking part, to show the structure identical with that of fig. 6.

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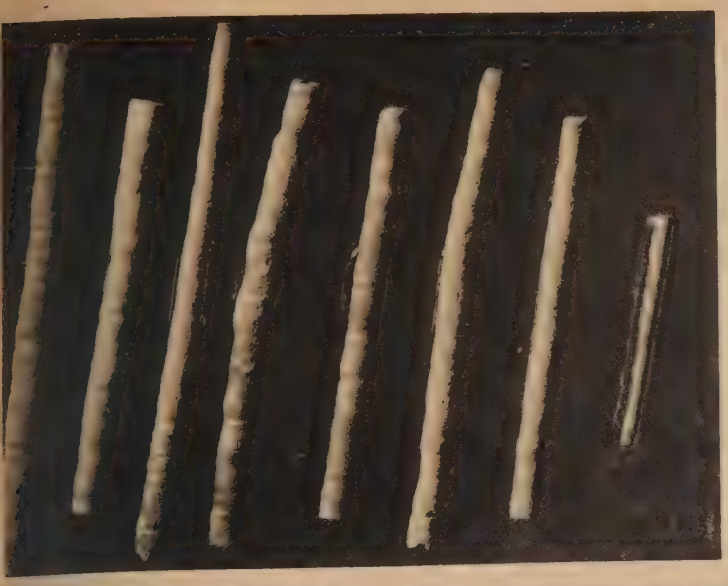
ASTRORHIZA, RHABDAMMINA.

PLATE XLIII.

Bathysiphon, Rhabdammina, Alveolina, Nodosinum.

Fig. 1. *Bathysiphon "rufescens"*; × 6.
Fig. 2. *Bathysiphon spec.*, (or *Hyperammina*); × 6.
Figs. 3 and 6. Central parts of *Rhabdammina abyssorum*, some of which (centre of fig. 3!) show the bifurcating stolons; × 7.
Fig. 4. Distal parts of *Rhabdammina abyssorum*, broken off and hitherto known as *R. irregularis*; × 7.
Fig. 5. Individuals of *Bathysiphon rufus*, × 4.
Fig. 7. Longitudinal section through the protoplasm of *Alveolinella*, showing the first chambers, filled up with protoplasm; × 24.
Fig. 8. Several specimens of *Nodosinum gaussicum*; × 7.



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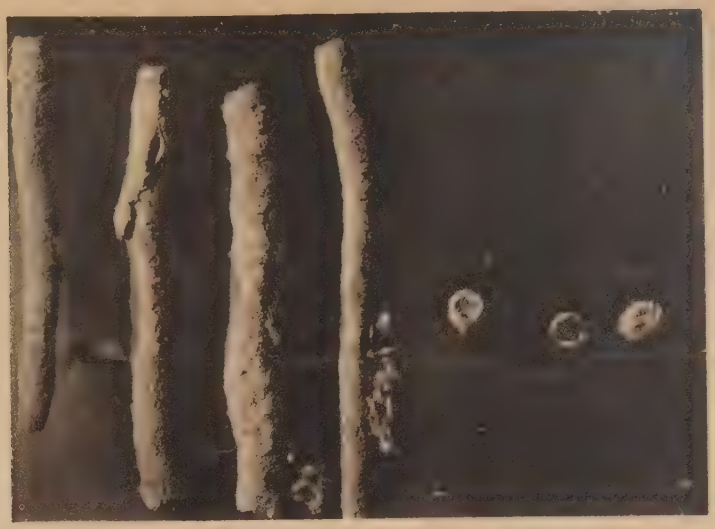

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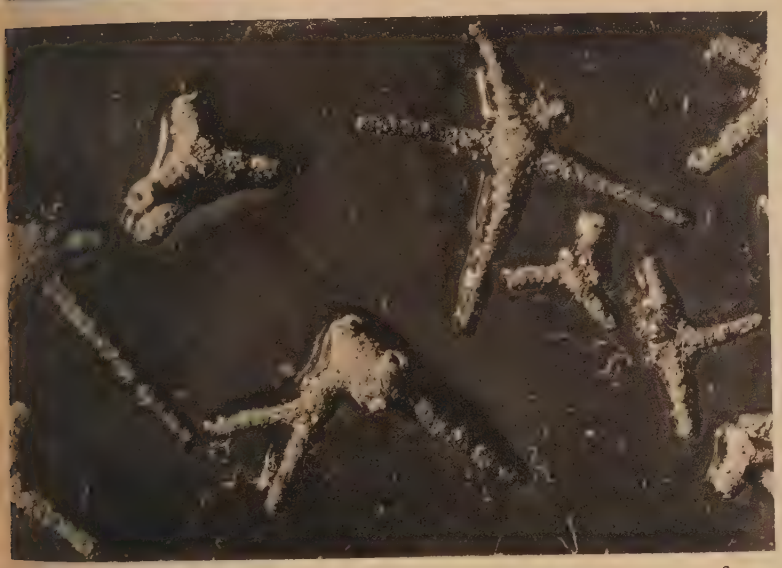

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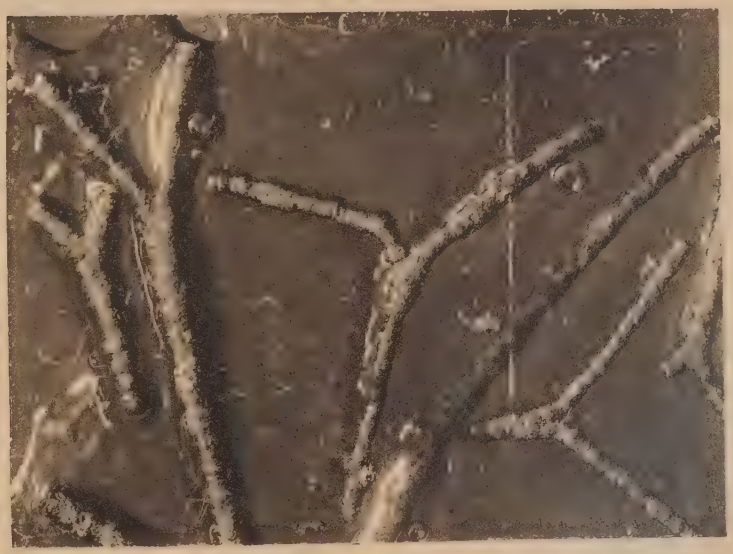

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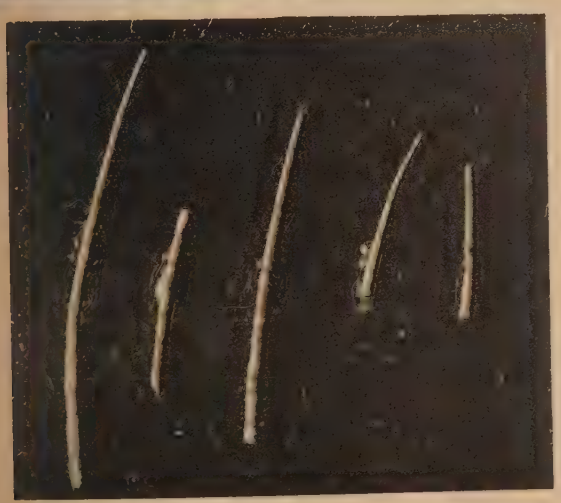

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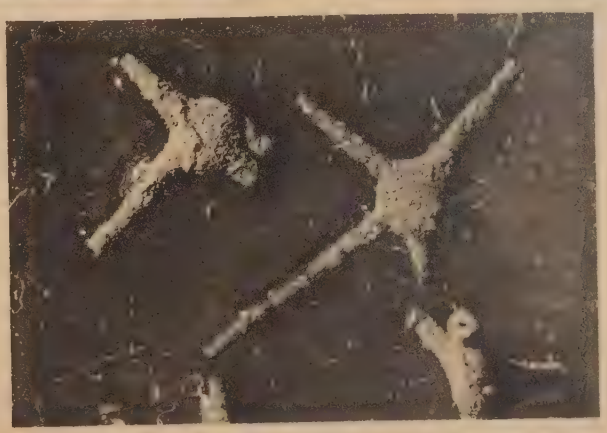

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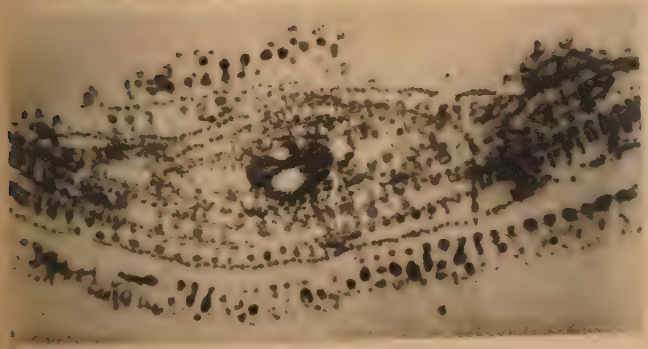

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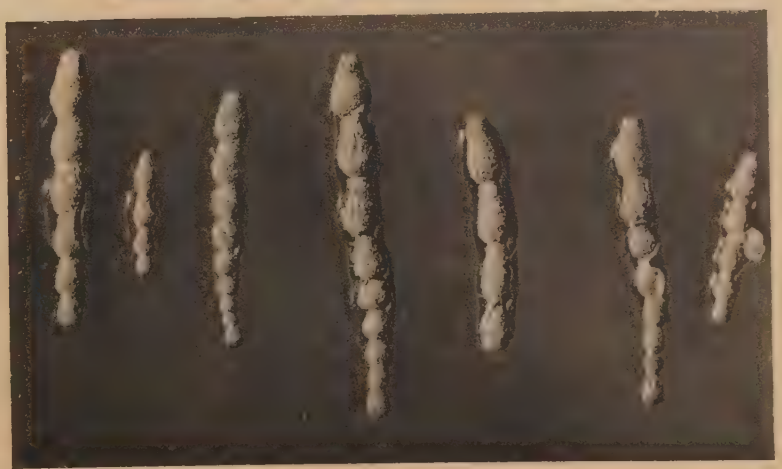

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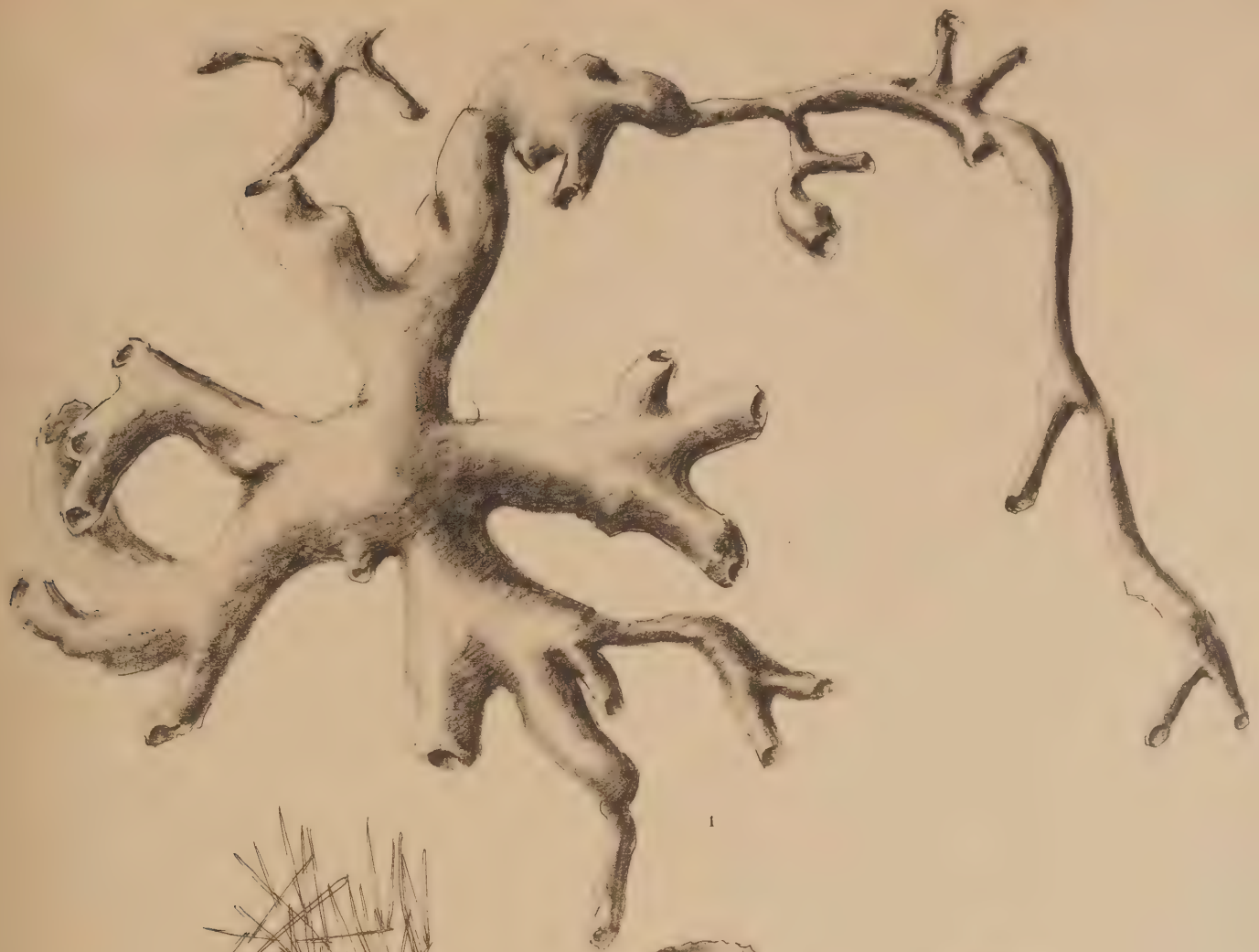
BATHYSIPHON, RHABDAMMINA, ALVEOLINELLA, NODOSINUM.

PLATE XLIV.

Astrorhiza, Aschemonella.

Fig. 1. Beautifully preserved specimen of *Astrorhiza arenaria*, with outgrown stolons identical with *Rhizammina algaeformis*; × 12.
Fig. 2. Arrangement of the sponge-spicules in the wall of a chamber of *Aschemonella*; × 45.
Fig. 3. Mouth of *Aschemonella* with spiculae; × 45.
Fig. 4. Chambers of *Aschemonella* with long stolons, × 12.
Fig. 5. Three chambers of *Aschemonella*, connected by branching stolons; × 12.



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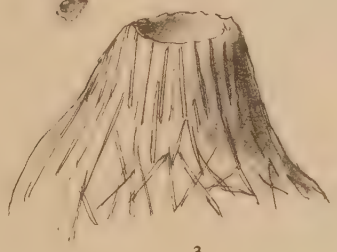

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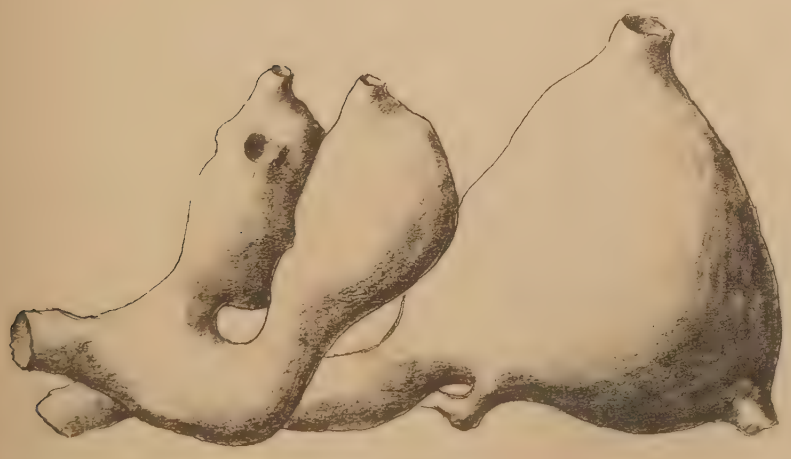

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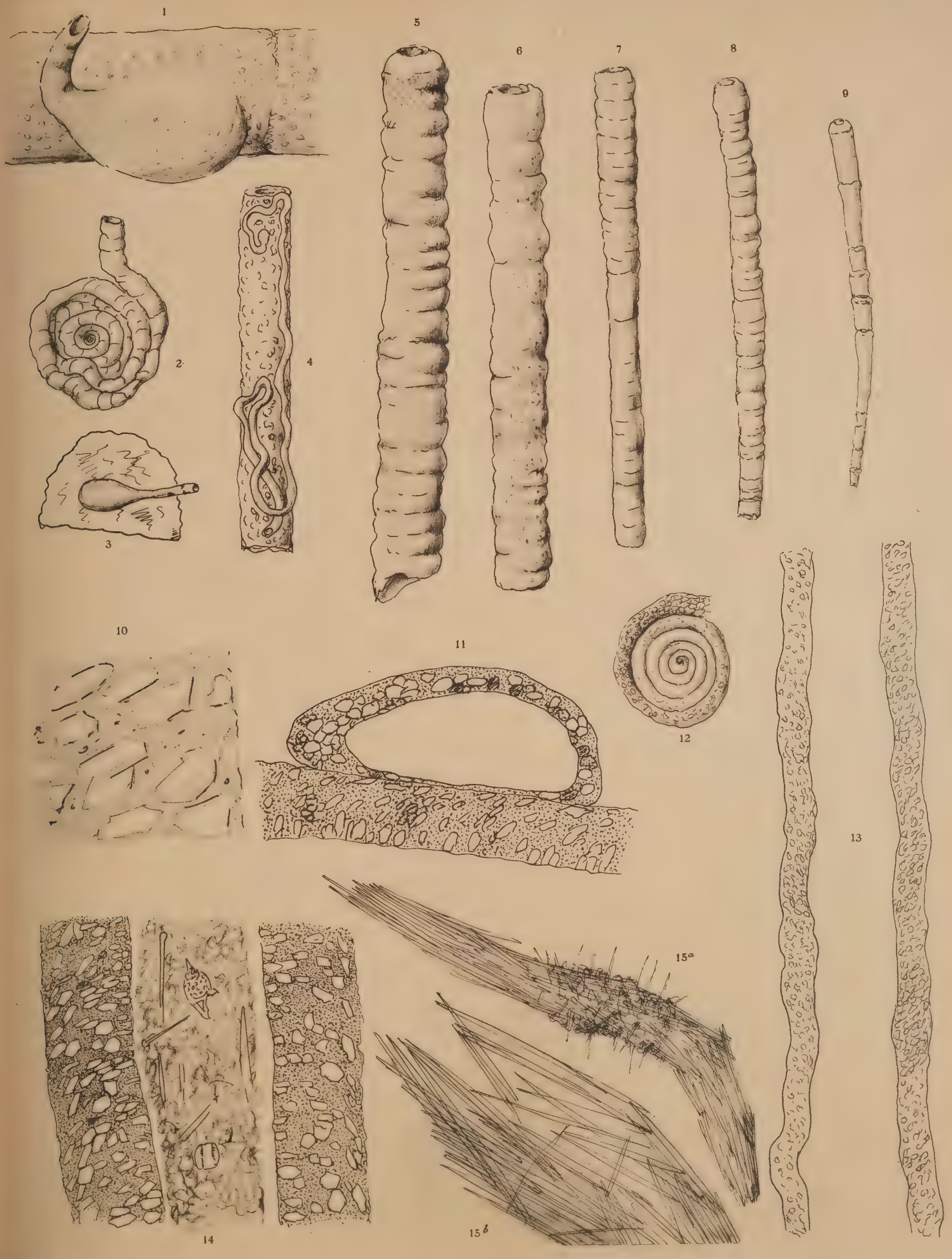
ASTRORHIZA, ASCHEMONELLA.

PLATE XLV.

Bathysiphon rufus, Marsipella elongata.

Fig. 1. "*Ammolagena clavata*", on *B. rufus*; × 24; showing an arenaceous structure.
Fig. 2. "*Glomospira gordialis*"; × 12.
Fig. 3. "*Ammolagena clavata*"; × 12.
Fig. 4. "*Girvanella vagans*"; × 12, on *Bathysiphon.*
Figs. 5—9. *Bathysiphon rufus,* different stages of development; × 12.
Fig. 10. Part of a slide through the wall of *Bathysiphon rufus*; × 120.
Fig. 11. Slide, transverse through the shell of "*Ammolagena*", which was attached on *Bathysiphon rufus*; × 45.
Fig. 12. Central part of *Glomospira gordialis*; × 36.
Fig. 13. Longitudinal section of the individual of fig. 7, showing that the annular rings are also found at the inner walls; × 4.
Fig. 14. Section through *Bathysiphon rufus,* walls with protoplasm. Though the protoplasm shows many other material incorporated, only sandgrains are found in the walls; × 45.
Fig. 15. *Marsipella elongata, a*: whole specimen, × 24; *b*: apertural end of a specimen, showing the arrangement of the sponge-spicules; × 110.



BATHYSIPHON RUFUS, MARSIPELLA ELONGATA.

PLATE XLVI.

Bathysiphon, Marginopora, Carpenteria.

Fig. 1. Section through *Omphalocyclus macropora* (= *Marginopora macropora*), from the senonian limestone of Maestricht; × 6.

Fig. 2. *Omphalocyclus* from Maestricht; × 6.

Fig. 3. *Bathysiphon flavidus*, two of yellowish, one of brown colour; × $1^1/_2$.

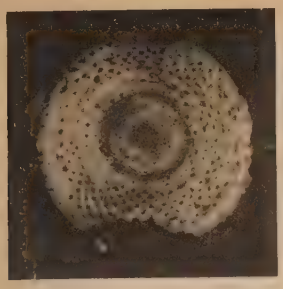
Fig. 4. Microspheric specimens of *Marginopora vertebralis*, showing especially the margin of the lacineate parts of the shell; × 6.

Fig. 5. *Carpenteria proteiformis*; × 6.

Fig. 6. *Marginopora vertebralis*, microspheric specimens, showing the cyclical arrangement of the central chambers; × 6.

Fig. 7. *Marginopora vertebralis*, microspheric, showing a very large development of the lacineate growth of the margin; × 6.

Fig. 8. *Bathysiphon filiformis*; × 2.



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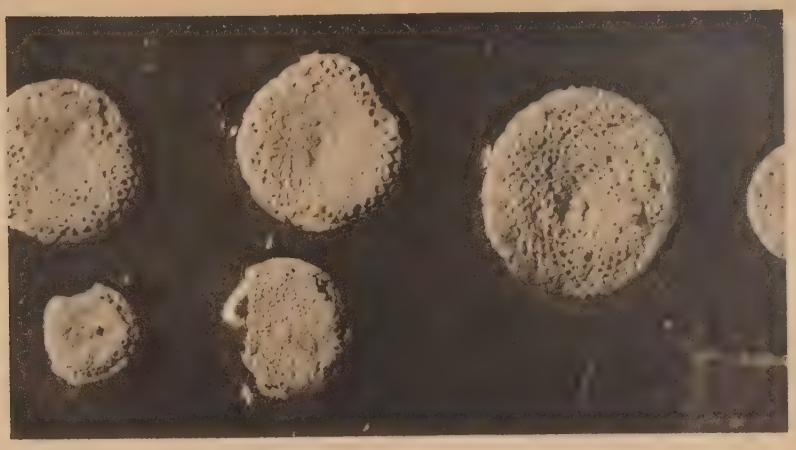

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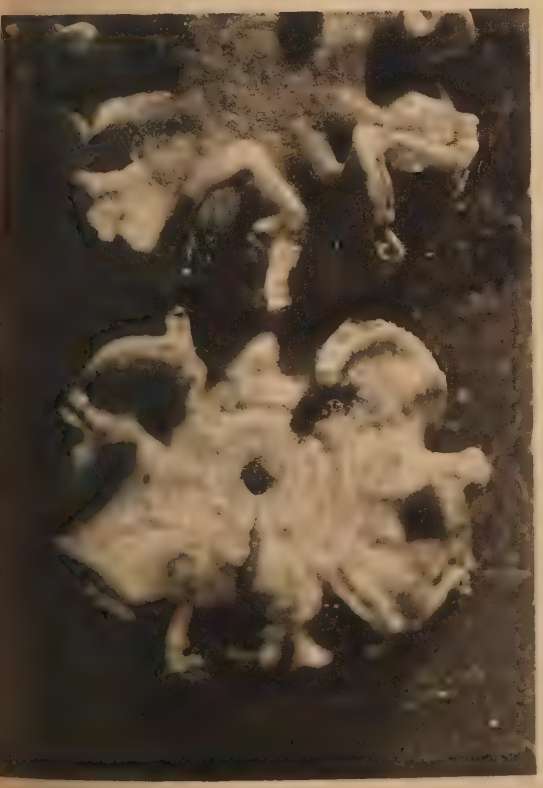

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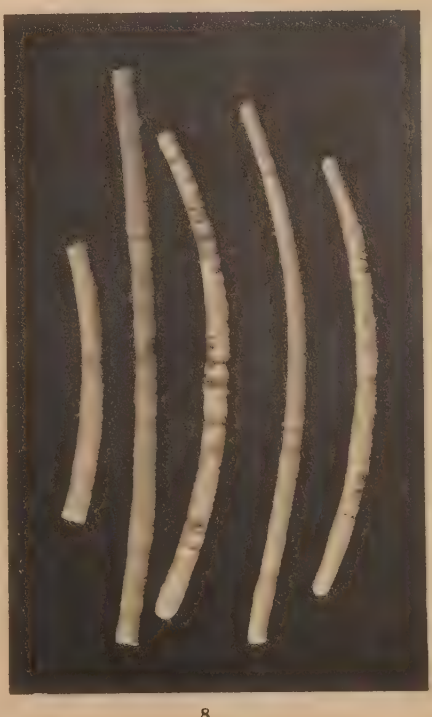

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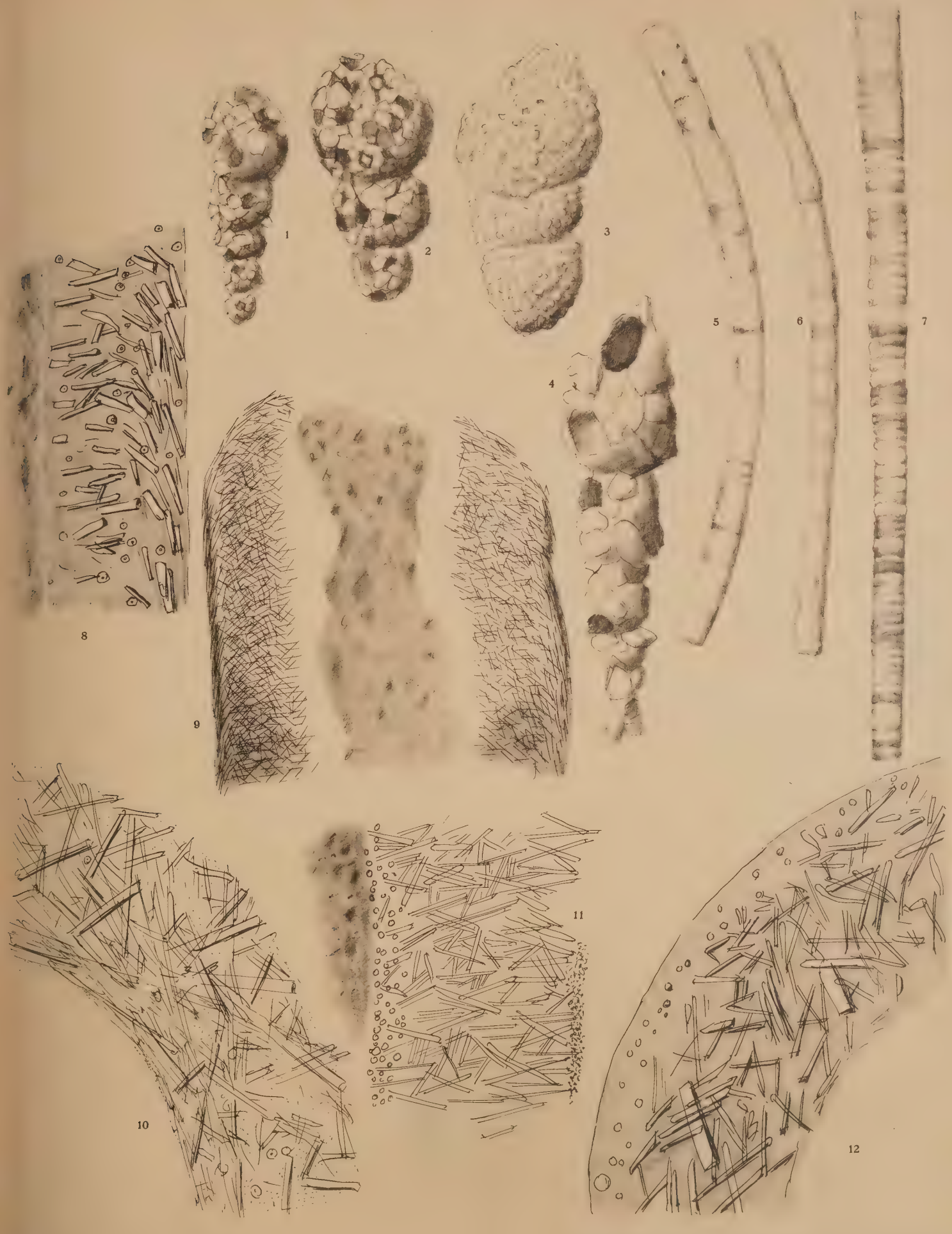
BATHYSIPHON, MARGINOPORA, CARPENTERIA.

PLATE XLVII.

Reophax, Bathysiphon.

Fig. 1. *Reophax pilulifer*, specimen, suggested to be of forma A_1; × 16.
Fig. 2. *Reophax pilulifer*, specimen, suggested to be of forma A_2; × 16.
Fig. 3. *Reophax dentaliniformis*; × 30.
Fig. 4. *Reophax scorpiurus*; × 30.
Figs. 5 and 6. *Bathysiphon filiformis*; × 6.
Fig. 7. *Bathysiphon flavidus*; × 6
Fig. 8. Longitudinal section of a shell of *Bathysiphon flavidus* with protoplasm; × 120.
Fig. 9. Longitudinal section through the upper end of *Bathysiphon flavidus*; × 60.
Fig. 10. Transverse section through the wall of *Bathysiphon filiformis*; × 120.
Fig. 11. Longitudinal section through *B. filiformis*, showing the inner layer of transversally arranged spiculae, and the outer one of dark organic material; × 120.
Fig. 12. Transverse section through the shell of *B. flavidus*, showing the outer layer of longitudinal spicules and the large quantity of organic matter; × 120.

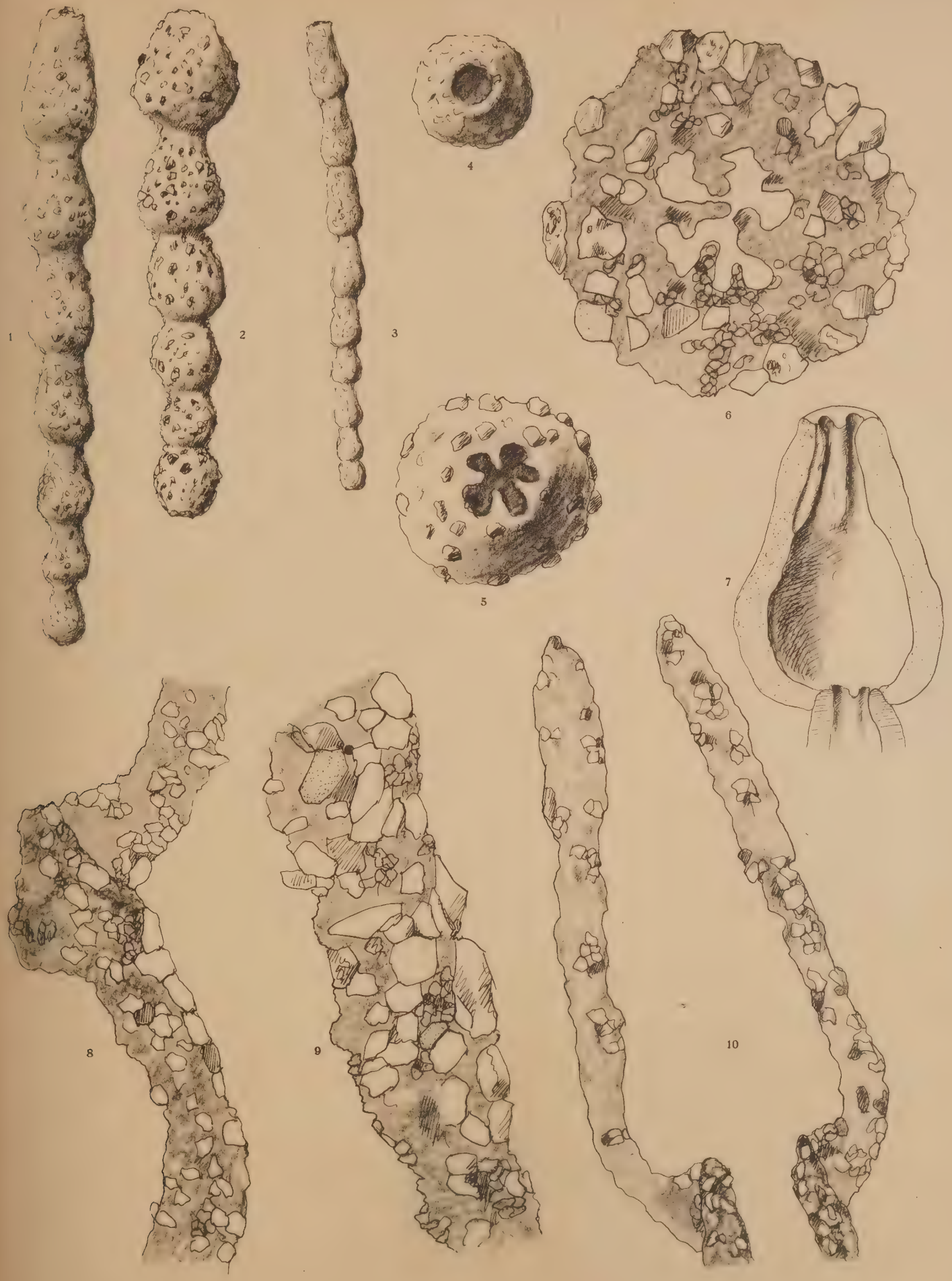


REOPHAX, BATHYSIPHON.

PLATE XLVIII.

Nodosinum gaussicum.

Fig. 1. Outgrown specimen of forma A_2; × 9.
Fig. 2. Specimen, somewhat different from the general type, but possessing a radiate mouth; × 9.
Fig. 3. Outgrown specimen of forma A_1, lacking the radiate mouth; × 15.
Fig. 4. Apertural face of forma A_1.
Fig. 5. Apertural face of forma A_2.
Fig. 6. Transverse section through the apertural part of forma A_2, showing that the "Zotheken" are mainly composed of organic material; × 105.
Fig. 7. Longitudinal section through a chamber of forma A_2, showing the "Zotheken".
Fig. 8. Longitudinal section through the wall at the place, where the following chamber (the organic material of which shows a brighter colour) is built on the apertural wall of the former one; forma A_2; × 105.
Fig. 9. Longitudinal section through the wall of an outgrown specimen of forma A_2; × 105.
Fig. 10. Longitudinal section through the last formed chamber of a specimen of forma A_1; × 105.

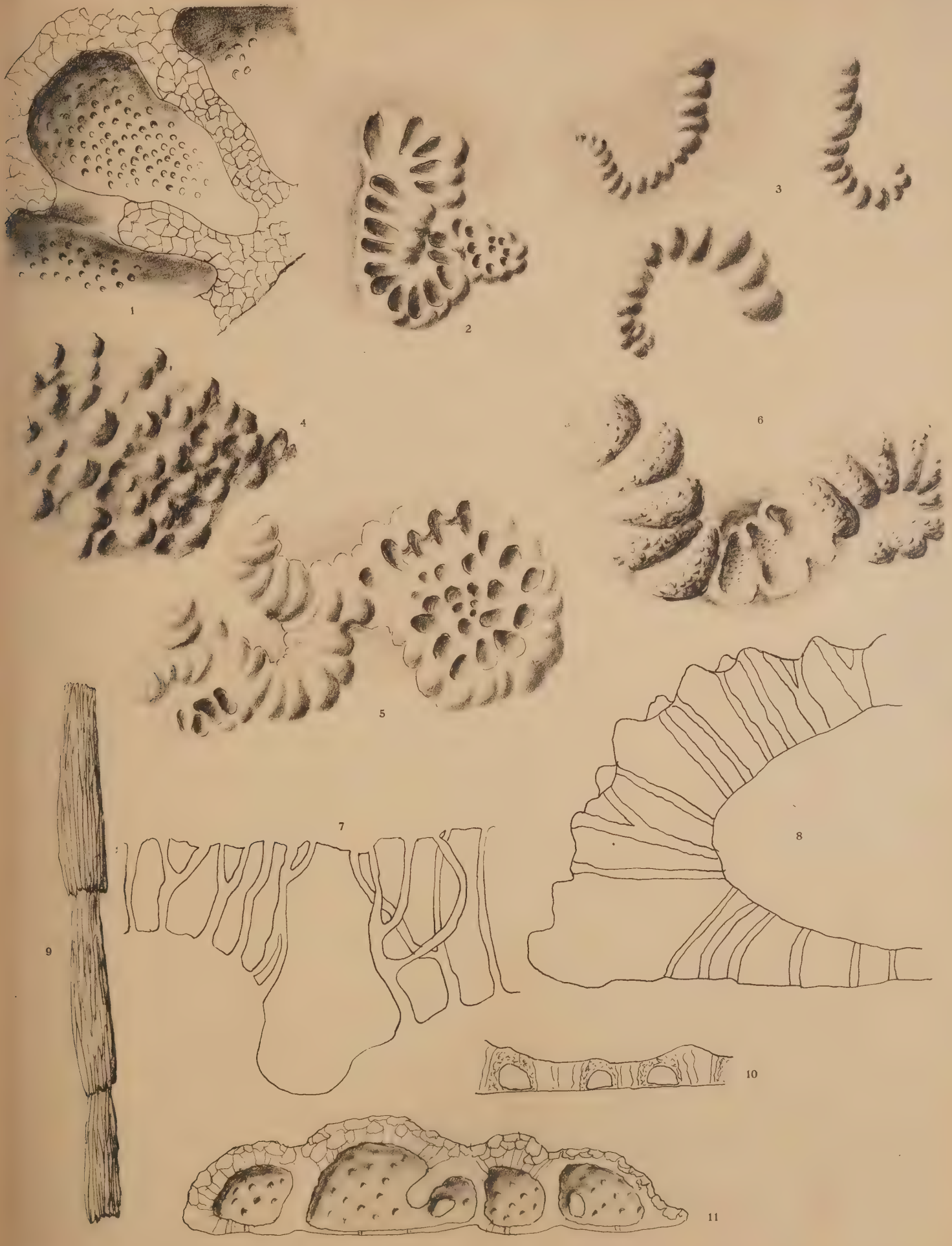


NODOSINUM GAUSSICUM.

PLATE XLIX.

Reophax, Placopsilina.

Fig. 1. Horizontal section through *Placopsilina cenomana*, showing the pores and the structure of the walls; × 240.
Fig. 2. Individual of *Placopsilina* (*Haddonia*), with partly removed walls to show the arrangement of chambers; × 30.
Fig. 3. Three specimens of *Placopsilina cenomana*; × 30.
Fig. 4. Outer surface of *Placopsilina cenomana*; × 30.
Fig. 5. *Placopsilina* (*Haddonia*), microspheric specimen, irregularly formed, walls of the coiled part removed; × 30.
Fig. 6. *Placopsilina cenomana*; × 60.
Fig. 7. Transverse section through the wall of two adjacent chambers, showing pores. Canadabalsam-preparation; × 675; *Placopsilina*.
Fig. 8. Section (from canadabalsam-preparation) of *Placopsilina*, showing pores and tubercules; × 675.
Fig. 9. Specimen of *Reophax spiculifer*; × 95.
Fig. 10. Longitudinal section through *Haddonia*-like specimen; × 40.
Fig. 11. Longitudinal section through *Placopsilina*; × 165.

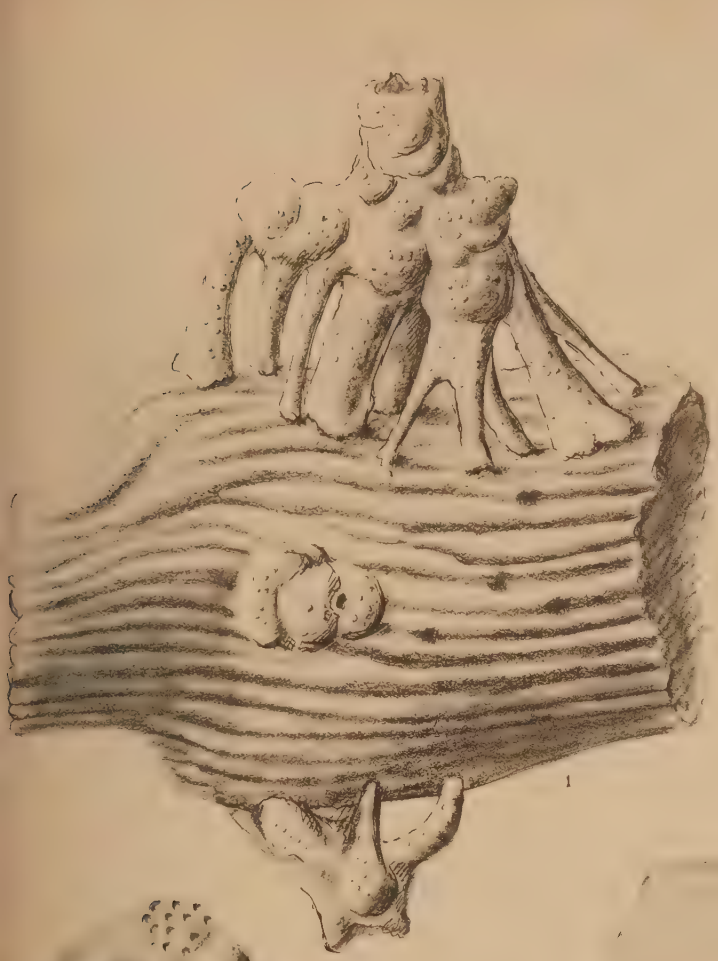


REOPHAX, PLACOPSILINA.

PLATE L.

Carpenteria utricularis.

Fig. 1. Three individuals of *Carpenteria utricularis*, forma A_2 (= *Ramulina herdmani*); in the centre a very young specimen, underneath an older one, uppermost an outgrown individual; × 8.
Fig. 2. Two individuals, forma A_2 (= *Carpenteria utricularis*), attached on coral; × 9.
Fig. 3. Section through a decalcified specimen of "*C. monticularis*", showing that the firstformed shell layer was thin, and that afterwards the wall is thickened, forming trumpet-shaped pores; × 180.
Fig. 4. Two individuals of *Carpenteria utricularis*, forma A_1 (= *C. monticularis*); × 9.
Fig. 5. Surface of forma A_2 (= *Ramulina herdmani*); × 120.
Fig. 6. Dorsal (attached and flattened) side of forma B (= *Anomalina polymorpha*), decalcified; × 60.
Fig. 7. Surface of forma A_2 (= *Carpenteria utricularis s. s.*); × 120.
Fig. 8. Surface of forma A_1 (*Carpenteria monticularis*); × 120.
Fig. 9. Section through the wall of "*Ramulina herdmani*"; × 120.
Fig. 10. Decalcified initial set of chambers of "*Carpenteria monticularis*" (= forma A_1); × 60.
Fig. 11. Decalcified initial set of chambers of "*Carpenteria utricularis*" (= forma A_2); × 60.
Fig. 12. Decalcified initial set of chambers of *Carpenteria utricularis* with the habitus of "*monticularis*", from Sebesi; × 60.
Fig. 13. Transverse section through the wall of *Carpenteria utricularis*, forma A_2 (with the network structure); × 120.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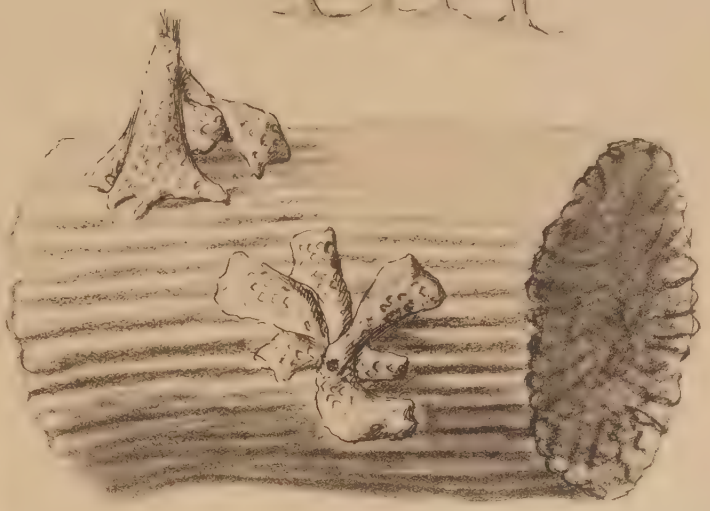
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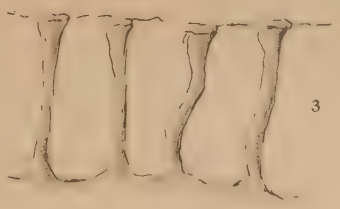
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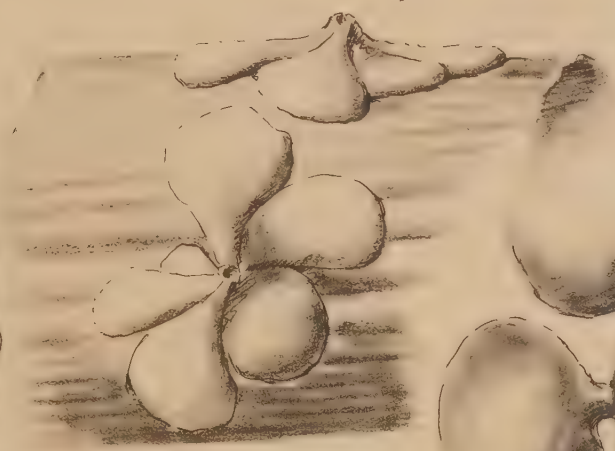
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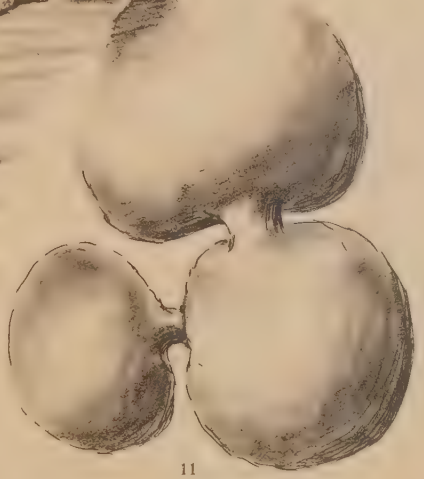
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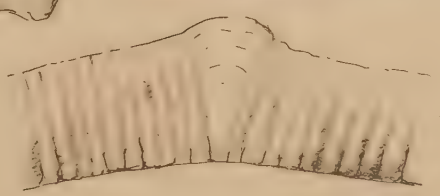
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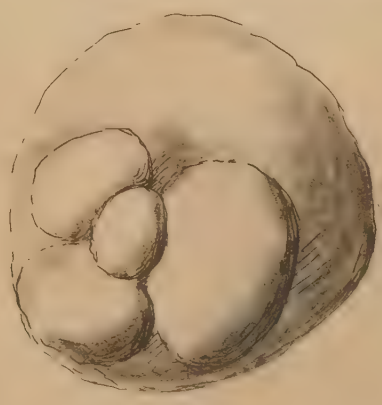
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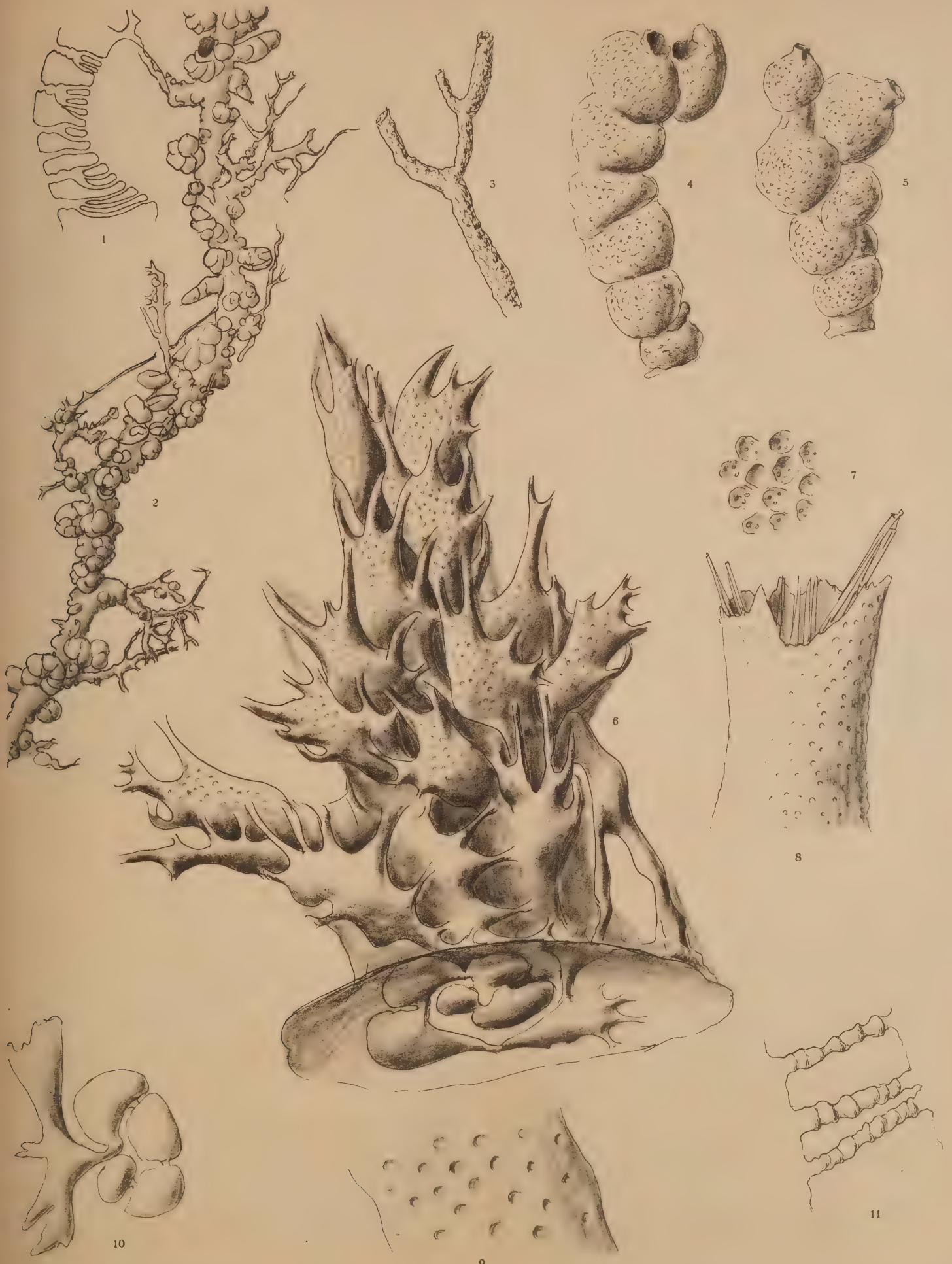
CARPENTERIA UTRICULARIS.

PLATE LI.

Rhizammina, Carpenteria.

Fig. 1. Section through the wall of *Carpenteria proteiformis*, showing the fusion of the pores before they reach the surface; × 210.
Fig. 2. *Rhizammina globigerinifera*; × 12.
Fig. 3. *Rhizammina algaeformis*; × 8.
Figs. 4 and 5. Two specimens of *Carpenteria proteiformis*; × 18.
Fig. 6. Decalcified specimen of *Carpenteria rhaphidodendron*, showing the initial set of chambers, the spiral arrangement of the later chambers around the stem, with their multitude of fingerlike outgrowths; × 40.
Fig. 7. Surface of *Carpenteria proteiformis*; × 210.
Fig. 8. End of a fingerlike outgrowth of a chamber of *Carpenteria rhaphidodendron*, serving as aperture; with sponge-spicules; × 120.
Fig. 9. Part of the surface of *Carp. rhaphidodendron*; × 220.
Fig. 10. Initial set of chambers of *C. rhaphidodendron*, seen from below; × 50.
Fig. 11. Wall of *C. rhaphidodendron*, with pores, showing growing-lines; × 400.



RHIZAMMINA, CARPENTERIA.

PLATE LII.

Carpenteria.

Fig. 1. Section through the wall of *Carp. utricularis* (= *Ramulina herdmani*), canadabalsam-preparation; × 200.
Fig. 2. Individual of *C. utricularis*, forma A_2; × 5.
Fig. 3. Individual of *C. utricularis*, forma A_1; × 5.
Fig. 4. Some specimens of *C. utricularis*, forma A_1 (= *C. monticularis*); × 5.
Fig. 5. Big colony of *C. utricularis*, forma A_2 (= *Ramulina herdmani*); × 2.
Fig. 6. Section through *C. proteiformis*; × 35.
Fig. 7. Part of a colony of *C. rhaphidodendron*; × 7.
Fig. 8. *Carp. proteiformis*; × 8.
Fig. 9. *C. utricularis*, forma A_2 (= *Ramulina herdmani*), showing initial set of chambers, pillars (stolons) and stem of chambers; × 5.
Fig. 10. Initial set of *C. utricularis*; × 50.
Fig. 11. Colony of *C. rhaphidodendron*; × 2.
Fig. 12. Part of a decalcified specimen of *C. rhaphidodendron*, showing the shape of the chambers; × 20.
Fig. 13. Decalcified base of *C. rhaphidodendron*, with four embryonic apparates; × 20.
Fig. 14. Canadabalsam-preparation of a section through *C. rhaphidodendron*; × 35.

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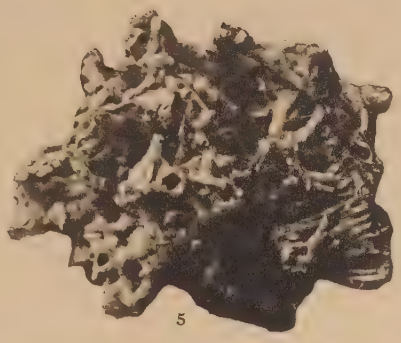

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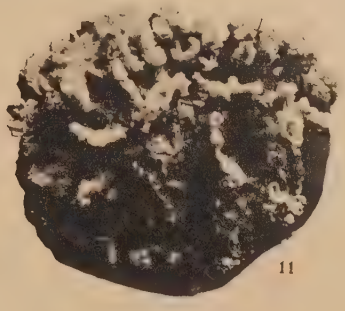

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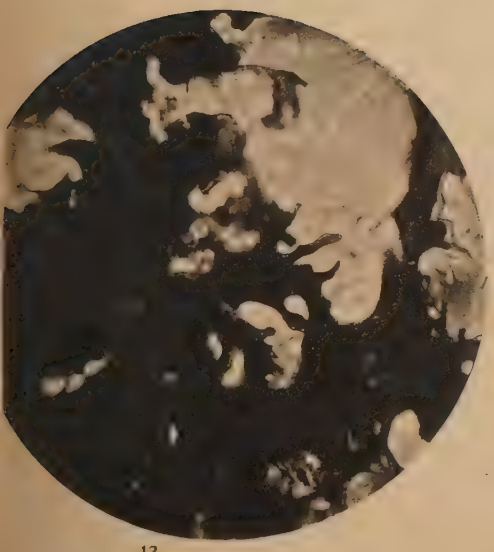

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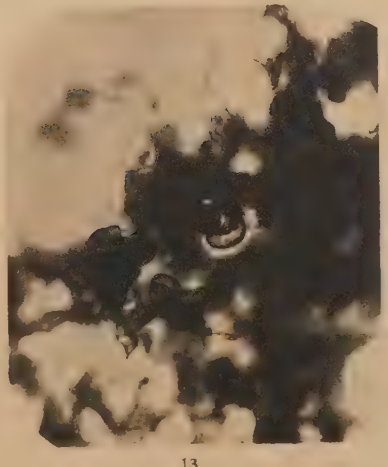

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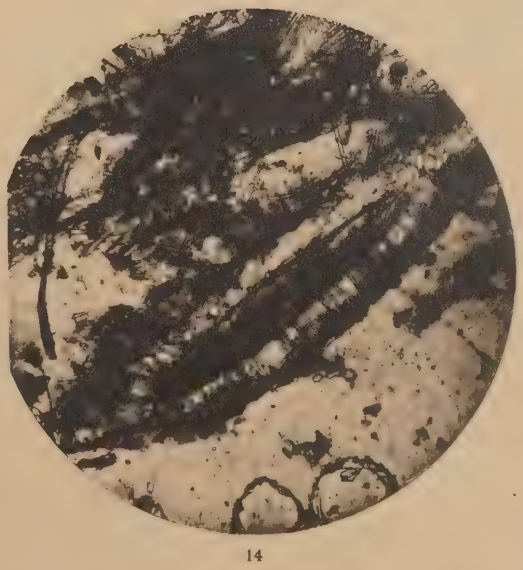

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CARPENTERIA.

PLATE LIII.

Peneroplis pertusus.

Figs. 1 and 2. Specimen of forma A_1, with typical dendritic aperture and overlapping later coils; × 36.
Figs. 3 and 4. Specimen of forma A_1, with overlapping later chambers, but nearly straight aperture; × 36.
Figs. 5 and 6. Specimen of forma A_1, with dendritic aperture, but not totally overlapping later coils; × 36.
Figs. 7 and 8. Forma A_1, with uncoiling later chambers, and single, though dendritic aperture; × 36.
Figs. 9 and 10. Very large specimen of forma A_1, showing the complicate aperture, consisting of a circle of foramina; × 36.
Fig. 11. Same specimen as fig. 9, apertural face of one of the chambers of the coiling part of the shell, showing a single, dendritic aperture; × 45.
Figs. 12 and 13. Uncoiling individual, forma A_2, showing the tendency to form a fan-shaped set of later chambers; × 36.
Figs. 14 and 15. Another specimen of forma A_1, with aberrant aperture; × 36.
Fig. 16. Apertural face of a very young specimen of forma A_1, showing the relatively simple aperture; × 90.

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PENEROPLIS PERTUSUS.

PLATE LIV.

Peneroplis pertusus.

Figs. 1 and 2. Specimen of forma A_2, showing, however, some features of A_1, especially with respect to its aperture; × 36.
Figs. 3 and 4. Young specimen of typical A_2; × 36.
Fig. 5. Apertural face of another young A_2-specimen; × 36.
Fig. 6. Apertural face of forma A_2; × 45.
Fig. 7. Apertural face of fan-shaped A_2, with a single row of apertures; × 36.
Fig. 8. Specimen of forma A_2; × 36.
Fig. 9. Specimen of forma B; × 36.
Fig. 10. Apertural face (partially) of forma B; × 45.
Figs. 11 and 12. Initial chambers of A_1 (as I mentioned in the text, forma A_2 in *Peneroplis* is that with the smallest first chamber); × 375.
Figs. 13 and 14. Initial chambers of A_2; × 375.
Fig. 15. Longitudinal section through the dendritic aperture of an individual of forma A_1; × 375.
Fig. 16. Initial chambers of A_2, transverse section; × 375.
Fig. 17. Same section as fig. 16, showing a part of the sectioned later chambers too; × 100.

PENEROPLIS PERTUSUS.

PLATE LV.

Peneroplis, Praesorites, Orbitolites.

Fig. 1. Section through forma A_1 of *Peneroplis pertusus*, showing the slow increasing of the height of the chambercoils; × 75.

Fig. 2. Section through forma A_2 of *Peneroplis pertusus*, fanshaped specimen; × 75.

Fig. 3. Section of fig. 7, highly enlarged to show the ridges of the chamberwalls, the very thick ventral walls of the later chambers; × 120; *Peneroplis.*

Fig. 4. Fanshaped microspheric specimen; × 35; *Peneroplis.*

Fig. 5. Young specimen of forma A_2; × 100; *Peneroplis.*

Fig. 6. Foraminifera from the Mediterranean, showing all the forms of *Peneroplis* together; × 16.

Fig. 7. Section through A_1-individual; × 30.

Fig. 8. Individual of the form with large megalospheric proloculum of *Praesorites orbitolitoides*, in transmitted light, showing the typical growth-ring in the later annular chambers; × 25.

Fig. 9. Central part of microspheric *Orbitolites marginalis*; × 75.

Fig. 10. Central part of microspheric *Praesorites orbitolitoides*, × 75.

Fig. 11. Central part of a megalospheric specimen (with large proloculum) of *Praesorites orbitolitoides*; × 75.

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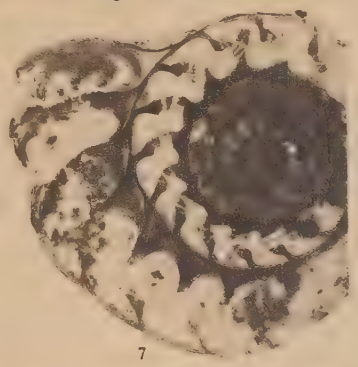

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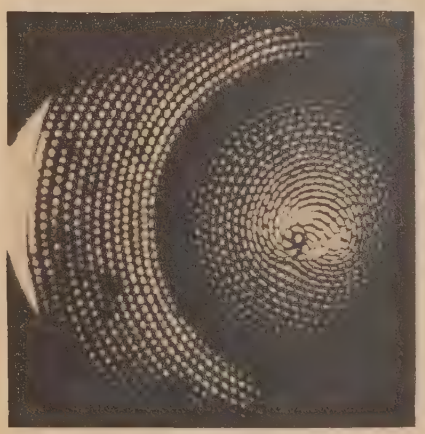

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PENEROPLIS, PRAESORITES, ORBITOLITES.

PLATE LVI.

Archaias discoideus.

Fig. 1. Megalospheric individual; × 60.
Fig. 2. Tangential section through the specimen of fig. 1, showing the passages of the flaring chambers, as well as those of the involving ones. Especially the passages of the latter are typically those of *Archaias*; × 60.
Fig. 3. First part of the shell of the microspheric specimen, somewhat schematical; × 375.
Fig. 4. Median section through the megalospheric specimen, showing the structural characteristics of the first whorls of chambers; × 110.
Fig. 5. Part of the external wall of a chamber of the megalospheric form; × 180.
Fig. 6. Total aspect of the microspheric individual; × 30.
Fig. 7. Tangential section through the flaring chambers of the microspheric specimen; showing the nature of the foramina; × 60.
Figs. 8 and 9. Two views on the marginal sides of the megalospheric individual; × 60.
Fig. 10. Median section through the flaring chambers of the megalospheric shell; × 110.
Fig. 11. Apertures of a flaring chamber of the B-form; × 110.
Fig. 12. Apertures of an outgrown flaring chamber of A-form; × 110.

ARCHAIAS DISCOIDEUS.

PLATE LVII.

Orbitolites, Praesorites, Marginopora.

Fig. 1. Microspheric specimen of *Marginopora vertebralis*; × 6.
Fig. 2. Megalospheric individual of *Marginopora vertebralis*; × 6.
Fig. 3. *Orbitolites* (= *Sorites*?) *marginalis*; × 6.
Fig. 4. *Praesorites orbitolitoides*; × 6.
Fig. 5. Microspheric specimen of *Orbitolites duplex*; × $3^1/_2$.
Fig. 6. Many specimens of *Praesorites orbitolitoides*; × 5, from the Mexican Gulf.
Fig. 7. *Orbitolites duplex*, megalospheric; × 6.

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ORBITOLITES, PRAESORITES, MARGINOPORA.

PLATE LVIII.

Praesorites orbitolitoides.

Fig. 1. Section through the central part of forma A_1, showing the pores of the proloculum, the arrangement of the foramina of the later chambers, and, schematically, the placing of the thin spots in the chamberwalls; × 400.

Fig. 2. Tranverse section through some chambers (the section is median) showing the thin spots in the walls and the incomplete walls between the chamberlets; × 600. The section is drawn from an A_2-individual.

Fig. 3. Section through a microspheric specimen; especially the peneropline spiral is sketched more distinctly, just as it is the case in fig. 1; × 400.

Fig. 4. Section through forma A_2, showing the proloculum, provided with pores; × 400.

Fig. 5. Optical section through the later (annular) whorls of chambers, showing the form of the foramina; × 400.

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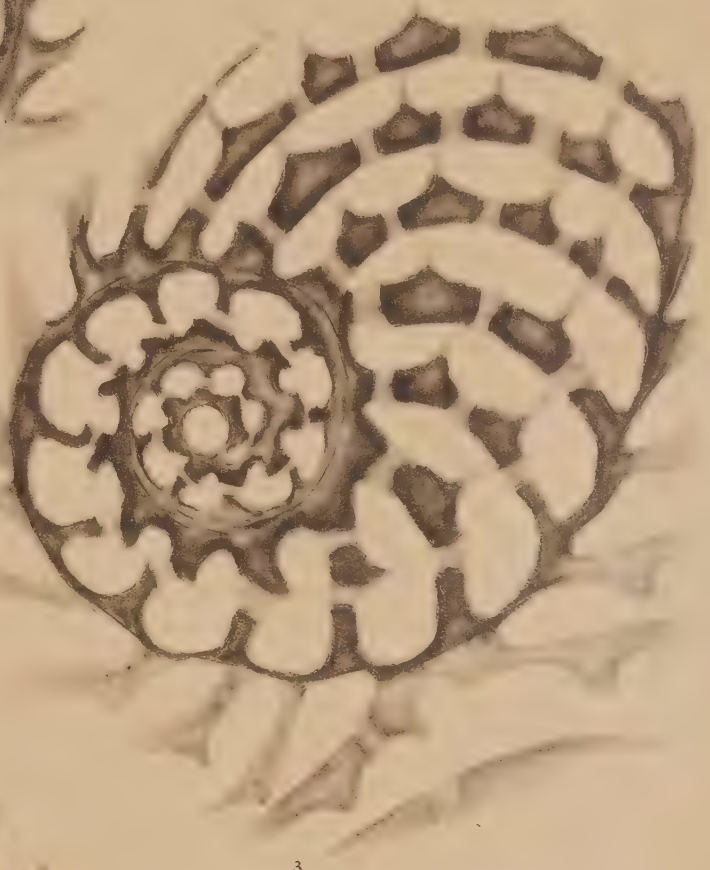

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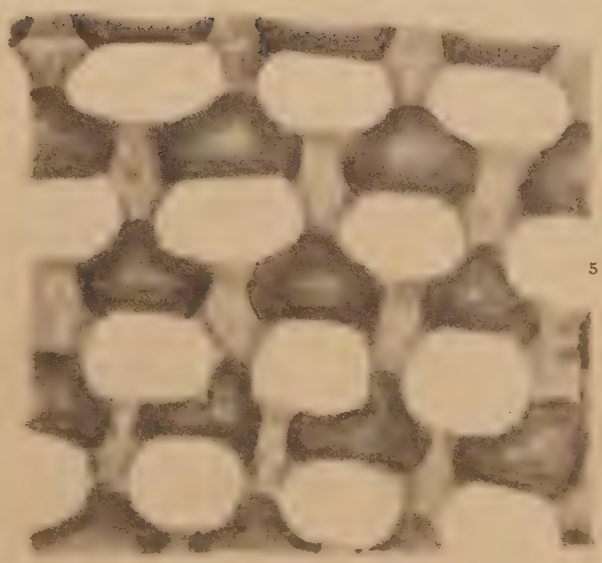

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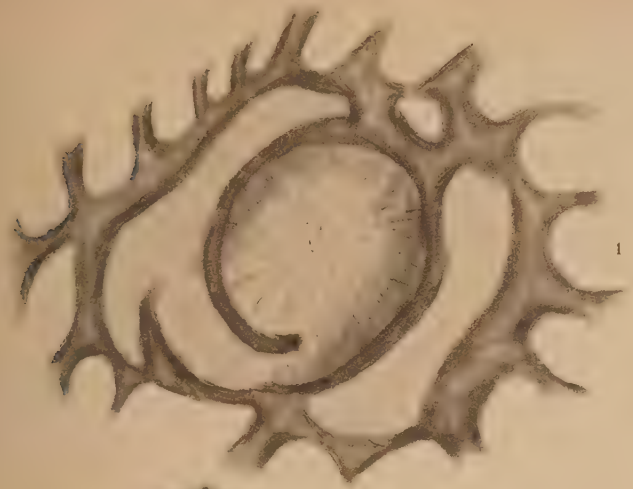
PRAESORITES ORBITOLITOIDES.

PLATE LIX.

Orbitolites (= *Sorites*?) *marginalis*.

Fig. 1. Section through the median part of forma A_1, proloculum showing pores; × 400.
Fig. 2. Section through the annular chambers of the margin of a B-individual, showing the typical orbitoline arrangement of the foramina; × 600.
Fig. 3. Section through an individual of forma A_2, with very large proloculum; only the third chamber is simple; the fourth is already divided into chamberlets; × 400.
Fig. 4. Section through the central part of forma B; × 400.
Fig. 5. Section through the central part of forma A_2, showing the wall of the proloculum and of the neck-chamber, possessing only thin spots on its wall; × 400.
Fig. 6. Marginal chambers of an A_2-individual, showing the fusing of the foramina; × 600.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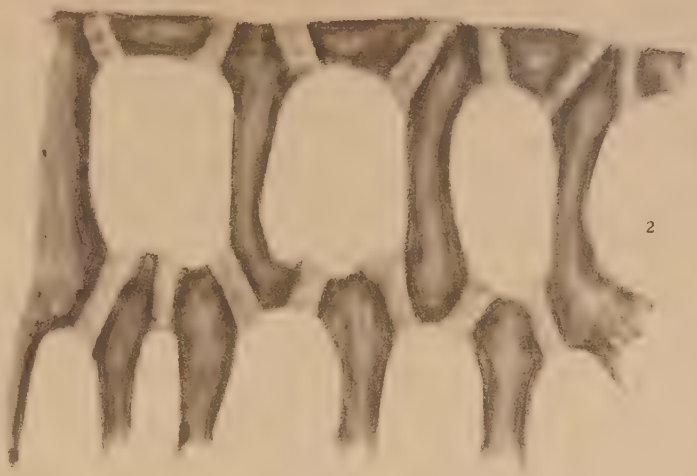
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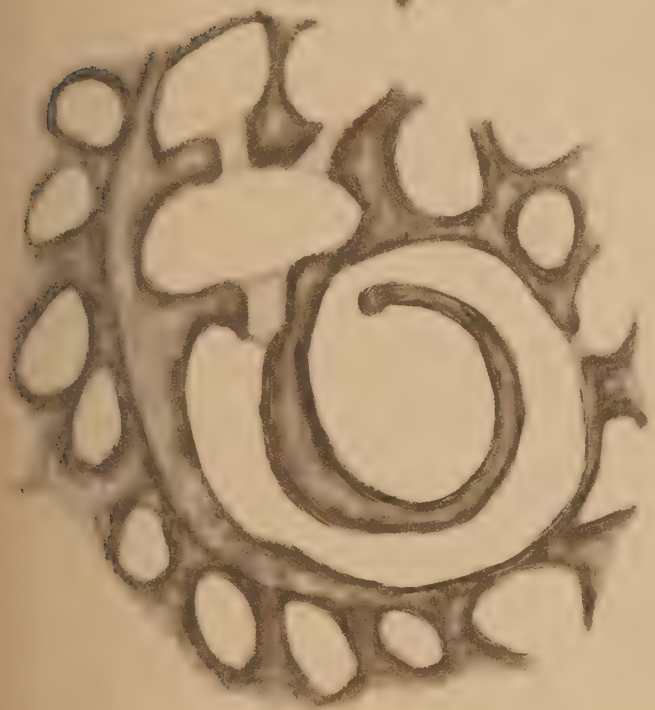
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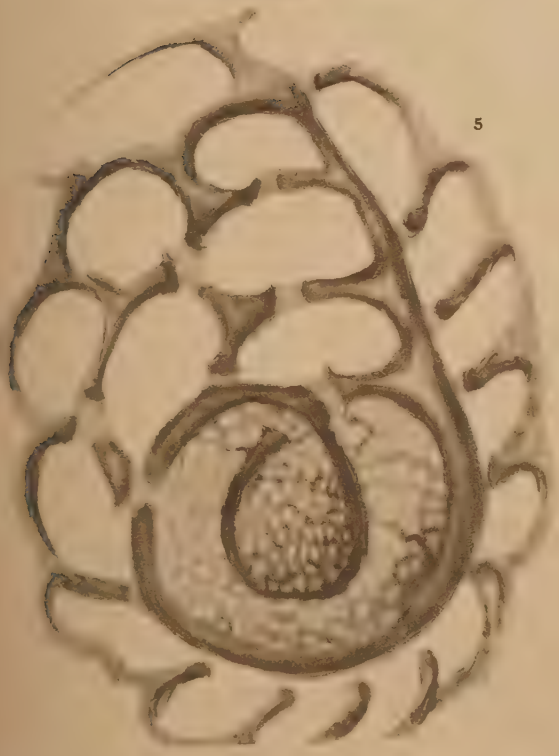
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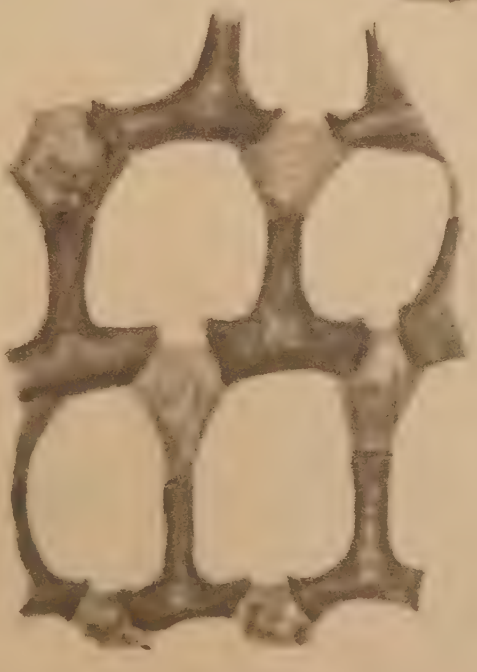
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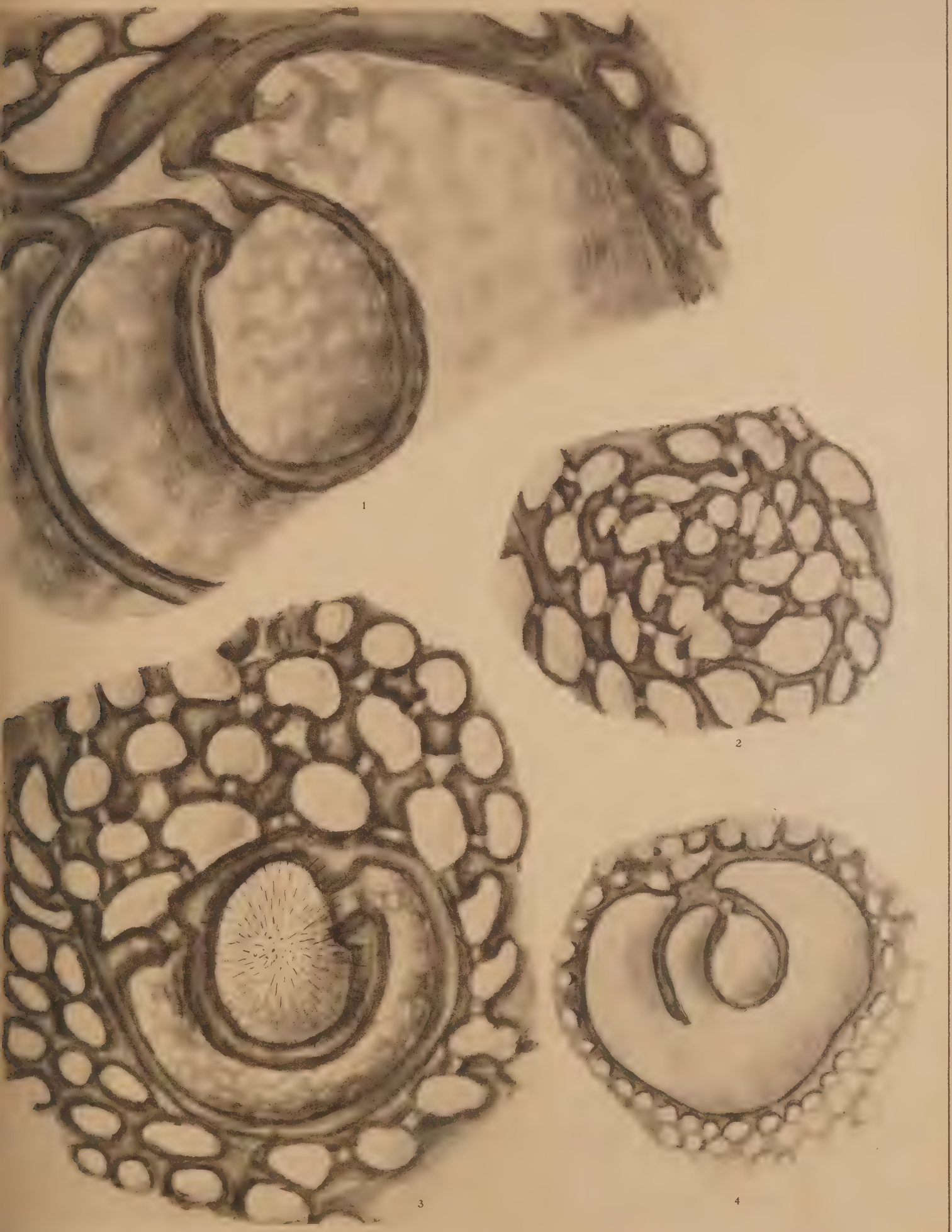
ORBITOLITES (=SORITES ?) MARGINALIS.

PLATE LX.

Orbitolites duplex.

Fig. 1. Part of the central disc of forma A_2; 400.
Fig. 2. Central part of the microspheric shell, showing the irregular spiral; × 400.
Fig. 3. Central part of forma A_1, with the pores of the initial chamber; × 400.
Fig. 4. Central part of the same specimen from fig. 1; × 120.



ORBITOLITES DUPLEX.

PLATE LXI.

Praesorites, Orbitolites, Marginopora, Alveolinella.

Fig. 1. Central part of the microspheric form of *Orbitolites marginalis*; × 200.
Fig. 2. A_2-individual of *Orbitolites* (= *Sorites*?) *marginalis*; × 30.
Fig. 3. A_1-specimen of *Praesorites orbitolitoides*; × 30.
Fig. 4. Transverse section through a canadabalsam-preparation of *Marginopora vertebralis*, forma A_1; × 28.
Fig. 5. Transverse section through forma A_2 of *Marginopora vertebralis*; canadabalsam-preparation; × 28.
Fig. 6. Transverse section through forma A_2 of *Orbitolites duplex*, canadabalsam-preparation; × 28.
Fig. 7. A_2-specimen of *Orbitolites marginalis*; × 30.
Fig. 8. Section through one of the ends of *Alveolinella Quoyi*, showing the complicated chamber ends; forma B; × 20.
Fig. 9. Longitudinal section through three chambers of megalospheric *Alveolinella Quoyi*; × 75.
Fig. 10. Transverse section through the A_1-form of *Alveolinella Quoyi*, showing the simple form of the first sets of chambers; × 75.
Fig. 11. Part of a canadabalsam-preparation of a transverse section through a microspheric shell of *Marginopora vertebralis*, showing the secondary chamberlets; × 40.
Fig. 12. Transverse section through forma A_1 of *Alveolinella Quoyi*; × 75.
Fig. 13. Transverse section through microspheric *Alveolinella Quoyi*; × 20.
Fig. 14. Central part of megalospheric specimen (with small proloculum) of *Praesorites orbitolitoides*; × 75.

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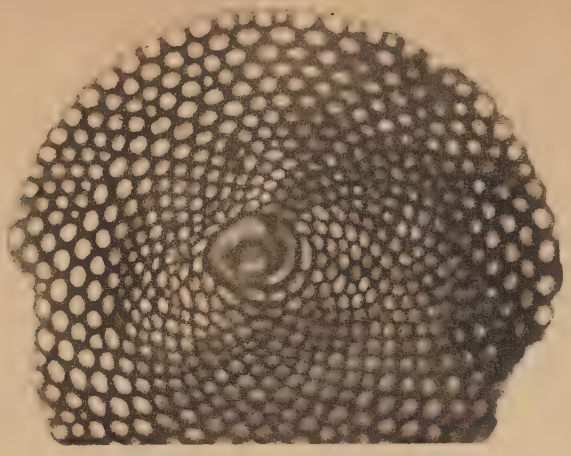

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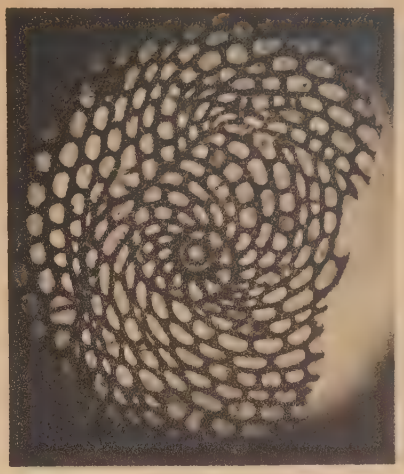

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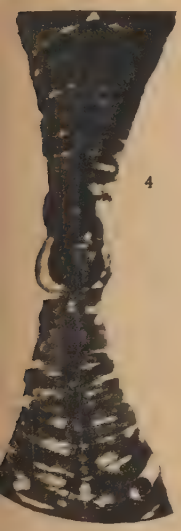

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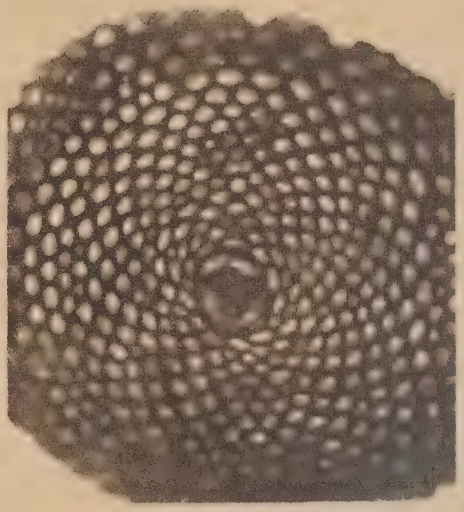

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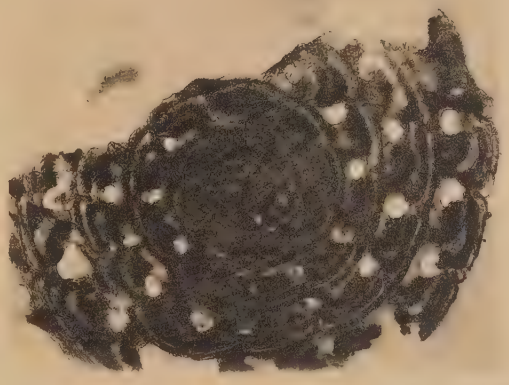

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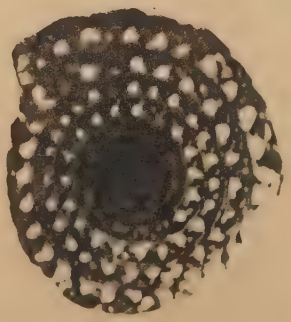

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PRAESORITES, ORBITOLITES, MARGINOPORA, ALVEOLINELLA.

PLATE LXII.

Marginopora, Orbitolites.

Fig. 1. Transverse section, canadabalsam-preparation, of a part near the centre of the shell of *Marginopora vertebralis*, forma A_1; × 125.

Fig. 2. Transverse section, canadabalsam-preparation, of a part near the centre of the shell of *Marginopora vertebralis*, forma A_2; × 125.

Fig. 3. Transverse section, *Marginopora*, forma B; × 125. The superficial chambers are shown and their connection with the inner ones.

Fig. 4. Central part of forma A_1, *Marginopora*; × 125.

Fig. 5. Apertural face of forma A_1, *Marginopora*; × 30.

Fig. 6. Superficial view of a canadabalsam-preparation of a total individual of megalospheric *Marginopora*, showing the nearly rectangular shape of the chambers; × 125.

Fig. 7. Central part of a section of megalospheric *Marginopora*, showing its conformity with *Orbitolites duplex*; only it is much more irregulary built; × 125.

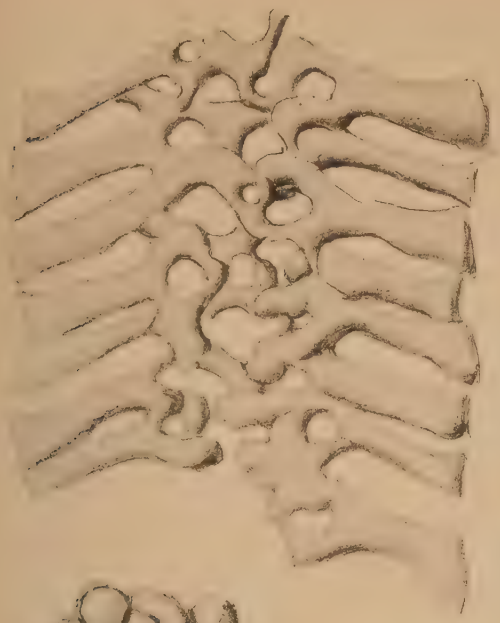
Fig. 8. Central part of forma B of *Marginopora*; × 125.

Fig. 9. Central part of forma A_2 of *Marginopora*; × 125.

Fig. 10. Transverse section through *Orbitolites duplex*; canadabalsam-preparation; × 125.

Fig. 11. Apertural face of forma B of *Marginopora*; × 30.

Fig. 12. Apertural face of forma A_2 of *Marginopora*; × 30.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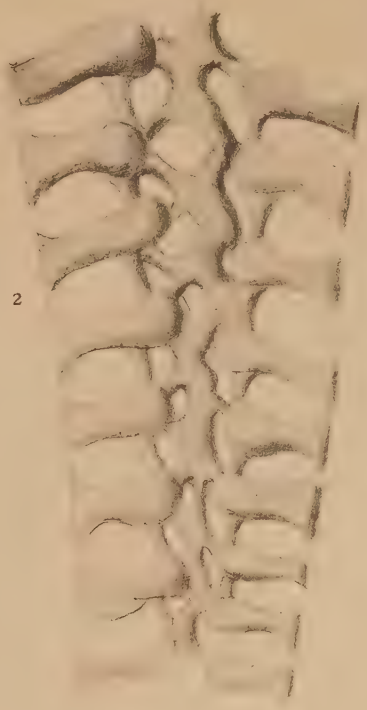
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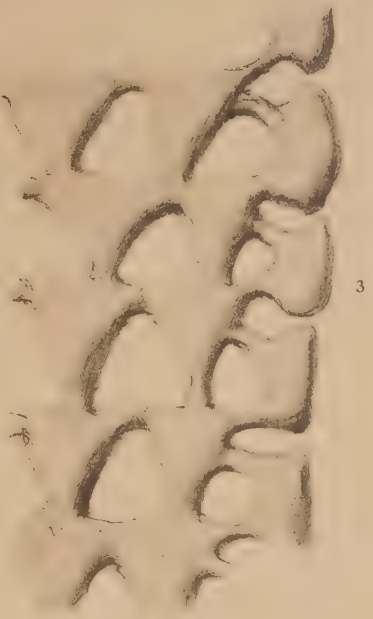
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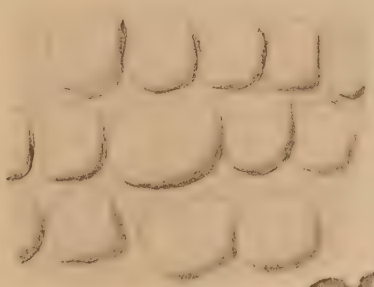
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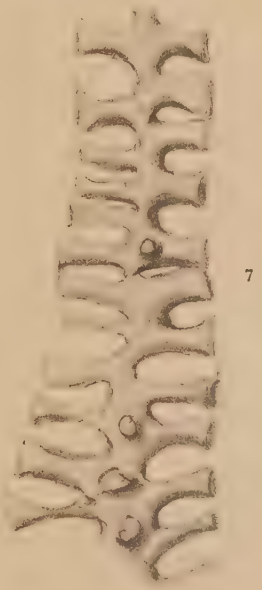
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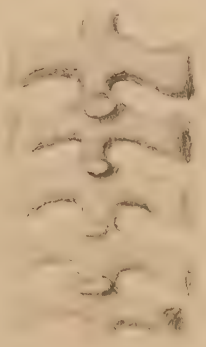
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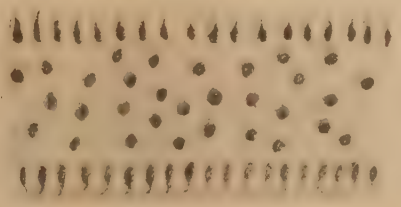
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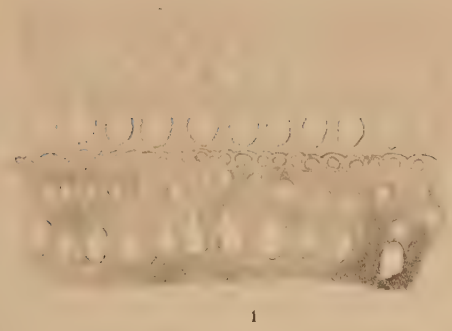
MARGINOPORA, ORBITOLITES.

PLATE LXIII.

Alveolinella Quoyi.

Fig. 1. Part of a longitudinal section of a megalospheric form; × 110.
Fig. 2. Schematical figure of the structure of the shell, from canadabalsam-preparations. The arrow indicates the direction of growth.
Fig. 3. Part of transverse section, canadabalsam-preparation, showing two coils of chamberlets. The dotted lines indicate the apertural ends of each chamberlet, the arrow the direction of growth; × 125.
Fig. 4. Megalospheric proloculum and three succeeding chambers, forma A_2; transverse section, showing the alveoline shape of the first chambers; × 600.
Fig. 5. Central part of a megalospheric form, showing the first chambers around the proloculum.
Fig. 6. Part of the apertural face of a megalospheric A_2-shell, showing the typical apertures of a "brood-chamber"; × 60.
Fig. 7. Same part, the apertural wall partly removed, to show the "brood-chamber" and the mouths of the "canals" leading to the foregoing chamber; × 60.
Fig. 8. Schematical figure of such a brood-chamber on transverse section; × 80.
Fig. 9. Central part of an univalent double-specimen; × 110.
Fig. 10. Total specimen of forma A_2; × 28.
Fig. 11. Proloculum of forma A_2, on transverse section; × 350.



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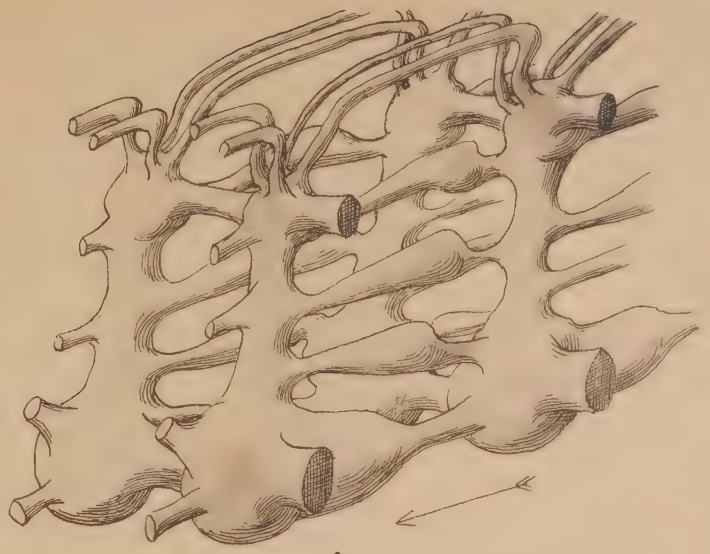

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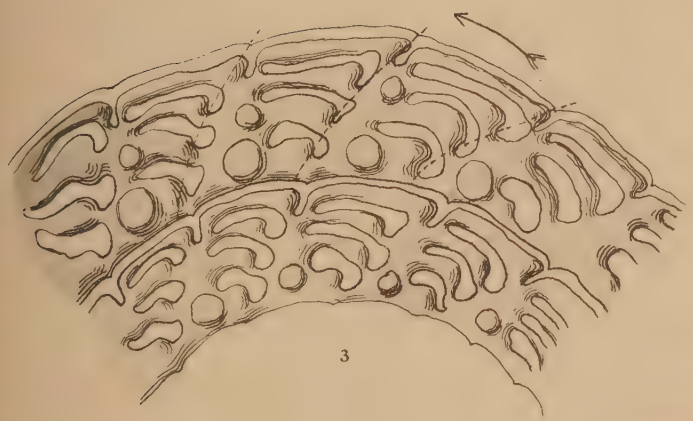

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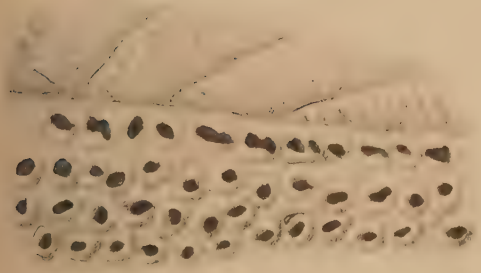

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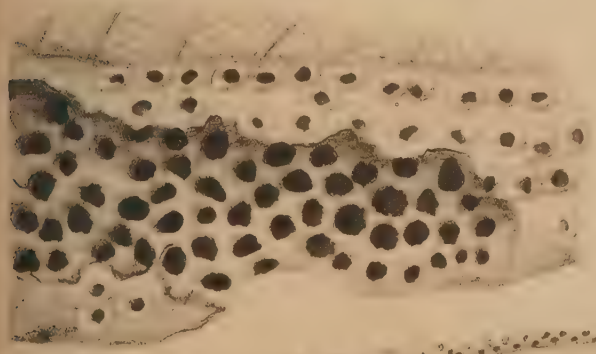

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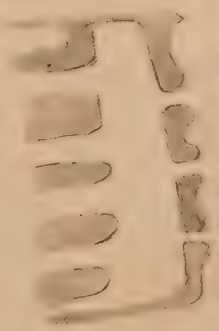

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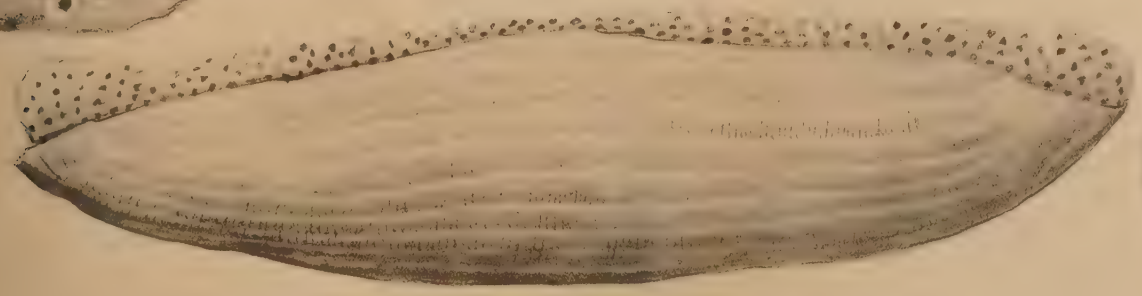

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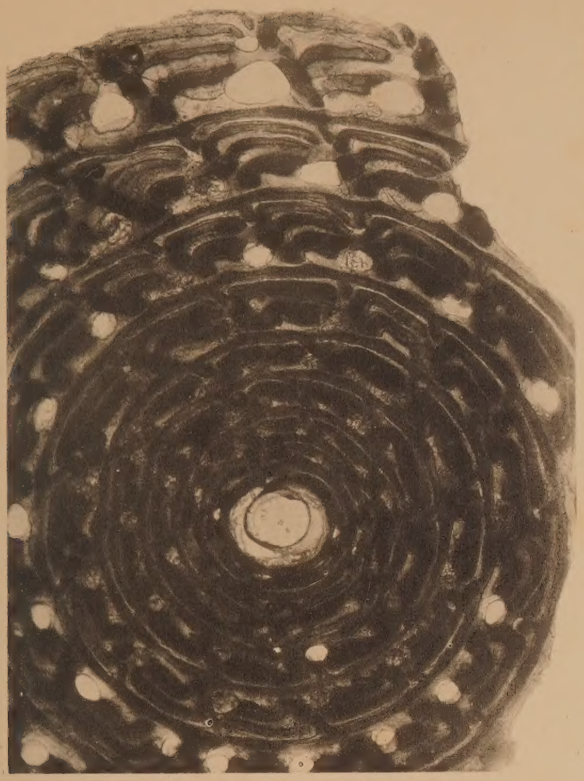
ALVEOLINELLA QUOYI.

PLATE LXIV.

Alveolinella Quoyi, Alveolina boscii.

Fig. 1. Transverse section through forma A_2; × 130.
Fig. 2. Transverse section through forma B; × 60.
Fig. 3. Longitudinal section through forma A_2, canadabalsam-preparation; × 50.
Fig. 4. Longitudinal section through forma A_1, canadabalsam-preparation, showing the ends of the chambers; × 50.
Fig. 5. Longitudinal section through *Alveolina boscii* from the eocene of Paris; × 50.
Fig. 6. Longitudinal section through the "broodchambers" of microspheric *Alveolinella*; × 50.



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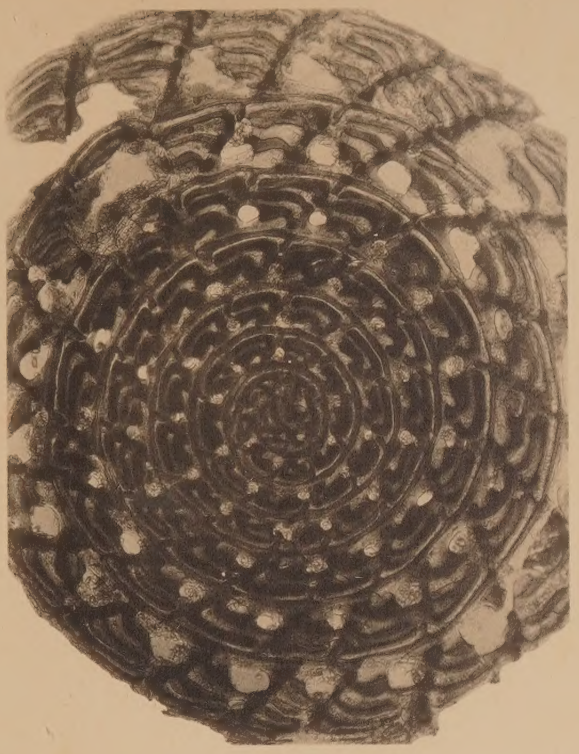

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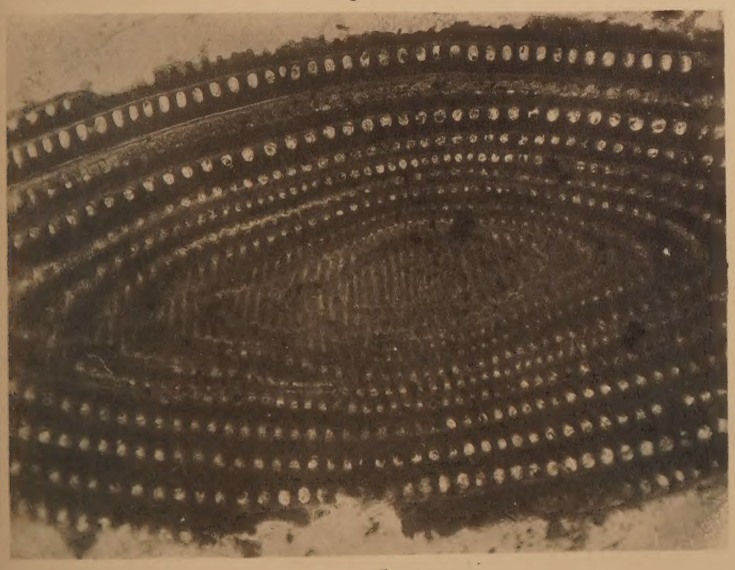

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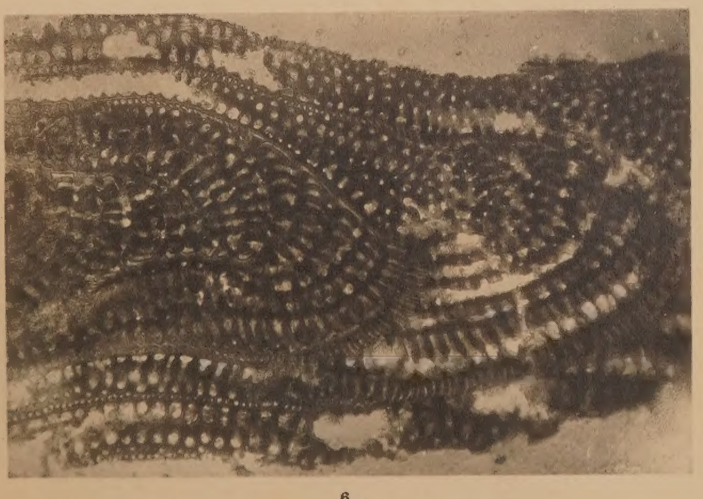

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ALVEOLINELLA QUOYI, ALVEOLINA BOSCII.